How Can We Use Chemical Reactions to Design a Solution to a Problem?

DEVELOPER: OpenSciEd

GRADE: Middle School **| DATE OF REVIEW:** July 2021

Educators Evaluating Quality Instructional Products

NextGen Science WestEd

How Can We Use Chemical Reactions to Design a Solution to a Problem?

EQuIP RUBRIC FOR SCIENCE EVALUATION

OVERALL RATING: E
TOTAL SCORE: 9

CATEGORY I: NGSS Three-dimensional Design Score	CATEGORY II: NGSS Instructional Supports Score	CATEGORY III: Monitoring NGSS Student Progress Score
3	3	3

Click here to see the scoring guidelines.

This review was conducted by the Science Peer Review Panel using the EQuIP Rubric for Science.

CATEGORY I CRITERIA RATINGS			CATEGORY II CRITERIA RATINGS			CATEGORY III CRITERIA RATINGS		
A.	Explaining Phenomena/ Designing Solutions	Extensive	**A.**	Relevance and Authenticity	Extensive	**A.**	Monitoring 3D Student Performances	Extensive
B.	Three Dimensions	Extensive	**B.**	Student Ideas	Adequate	**B.**	Formative	Extensive
C.	Integrating the Three Dimensions	Extensive	**C.**	Building Progressions	Adequate	**C.**	Scoring Guidance	Adequate
D.	Unit Coherence	Extensive	**D.**	Scientific Accuracy	Extensive	**D.**	Unbiased Tasks/Items	Extensive
E.	Multiple Science Domains	Adequate	**E.**	Differentiated Instruction	Adequate	**E.**	Coherence Assessment System	Extensive
F.	Math and ELA	Extensive	**F.**	Teacher Support for Unit Coherence	Extensive	**F.**	Opportunity to Learn	Extensive
			G.	Scaffolded Differentiation Over Time	Adequate			

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Summary Comments

Thank you for your commitment to students and their science education. NextGenScience is glad to partner with you in this continuous improvement process. It is obvious that this unit was thoughtfully crafted, and it has many strengths including:

- All lessons and student activities are connected to an anchoring phenomenon and problem to solve in a coherent way. The problem students are trying to solve is a real-life problem that has real impact on people and the materials ensure students will be invested in the phenomenon and problem and want to design an effective solution. The reviewers were especially impressed with the use of the stakeholder surveys to connect the phenomenon and the design solutions to the students' home, neighborhood, and community. This is very effective at ensuring relevance of the problem and the solutions to the students' lives.
- Students are continually engaged in using elements of all three dimensions throughout the unit and regularly engaged in three-dimensional learning as they make sense of phenomena and design solutions. The majority of student activities, products, and assessments integrate elements from all three dimensions simultaneously.

During revisions, the reviewers recommend paying close attention to the following areas.

- Scoring guidance could be improved by providing assessment support at the element level with a range of student answers and suggestions for teacher feedback/modifications to lessons based on those varied responses.
- Additional opportunities for students to receive teacher and peer feedback, be able to reflect on that feedback, and modify their models and designs based on feedback would strengthen the unit.

Note that in the feedback below, black text is used for either neutral comments or evidence the criterion was met and purple text is used as evidence that the criterion was not met.

All page numbers listed refer to the Teacher's Edition unless otherwise indicated.

CATEGORY I

NGSS 3D DESIGN

I.A. EXPLAINING PHENOMENA/DESIGNING SOLUTIONS

I.B. THREE DIMENSIONS

I.C. INTEGRATING THE THREE DIMENSIONS

I.D. UNIT COHERENCE

I.E. MULTIPLE SCIENCE DOMAINS

I.F. MATH AND ELA

How Can We Use Chemical Reactions to Design a Solution to a Problem?

EQuIP RUBRIC FOR SCIENCE EVALUATION

I.A. EXPLAINING PHENOMENA/DESIGNING SOLUTIONS

Making sense of phenomena and/or designing solutions to a problem drive student learning.

i. Student questions and prior experiences related to the phenomenon or problem motivate sense-making and/or problem solving.

ii. The focus of the lesson is to support students in making sense of phenomena and/or designing solutions to problems.

iii. When engineering is a learning focus, it is integrated with developing disciplinary core ideas from physical, life, and/or earth and space sciences.

Rating for Criterion I.A. **Explaining Phenomena/Designing Solutions**	Extensive *(None, Inadequate, Adequate, Extensive)*

The reviewers found extensive evidence that learning is driven by students making sense of phenomena and designing solutions to a problem because the lessons are organized so that students are figuring out the phenomenon of how flameless heaters work and designing a better solution to heating food with homemade materials. Students regularly return to the phenomenon and problem in every lesson and add layers of explanation and iterate on solutions based on their learning. Throughout the unit, students' questions create a need for engaging in learning about the phenomenon. Finally, students must develop grade-appropriate science ideas from **PS1.B: Chemical Reactions** to design their solutions to the unit problem and to explain the phenomenon of the flameless heater.

The focus of the lessons is to support students in making sense of phenomena and designing solutions to problems.

- Lesson 1: Students are shown pictures of people getting meals ready to eat (MREs) after a natural disaster and using a flameless heater for the food. Students also directly observe a flameless heater included in an MRE. Students also watch a video of a person eating a heated MRE. Students make a T-chart showing their "Notices" and "Wonders" about the phenomenon (pages 27–29).
- Lesson 1: Students create an initial model to explain how the flameless heater works. This model is revisited and revised in lessons 2, 3, and 4.
- Lesson 2: "Say, We ended up with a lot of questions and ideas to investigate last class! Let's prioritize where it makes sense to go next. To help us with that, let's recall what we accomplished last time… Use the *Design Questions Board* and *Ideas for Investigations* chart from Lesson 1 during this discussion to remind students of ideas they had and to add any new ideas. As ideas that are already listed on the *Ideas for Investigations* chart are talked about, note them, and as new ideas or more-specific ideas are surfaced, add those to the chart as well" (Teacher Edition, page 56). The lesson begins with students revisiting and prioritizing the questions they had on the Design Questions Board (DQB) concerning the flameless heater. This

leads to students planning investigations concerning the flameless heaters using hand warmers (Teacher Edition, pages 65–68).

- Lesson 3: “What did we figure out last time about using the materials in the MRE flameless heater or the hand warmer in our own designs?... For our homemade heater, what do we need the chemical reaction to do? What are our criteria for it?... I gathered some things from local places, like the grocery store and the hardware store. How can we figure out if some of these might work for our homemade flameless heater?” Students carry out investigations to determine household chemicals that could be used to make a flameless heater (Teacher Edition, page 86).
- Lesson 4: “Ask students to turn and talk with a partner: How can we systematically test what amount of each reactant will work best? After 1 minute, ask a few students to share their ideas. Students will likely suggest combining different amounts of each reactant and measuring the change in temperature” (Teacher Edition, page 125). Students carry out investigations to determine how much of each reactant could be used in their flameless heater design.
- Lesson 6: Students revisit the DQB and check off questions and investigations the class has addressed (Teacher Edition, page 166).
- Lesson 7: “Create a record of the most promising design characteristics. Display chart paper to record the class discussion of the most promising design characteristics. Encourage students to record revision ideas in their notebook as they listen to teams share their designs and identify the most promising design characteristics. Tell students that they will have the opportunity in Lesson 8 to consider the feedback and questions they have received as well as consider other revision ideas” (Teacher Edition, page 191). The class discusses what characteristics were most successful in meeting the design criteria and constraints for a homemade flameless heater.
- Lesson 8: Students examine how different changes to their flameless heater designs might affect different stakeholders.
- Lesson 9: Students complete their designs for homemade flameless heaters and share with other groups and reflect.

Student questions and prior experiences related to the phenomenon or problem motivate sense-making and problem solving. For example:

- Lesson 1: Students define a problem to design a solution based on the flameless heater they observed. Students work on design solutions and modify or test solutions for this problem during all lessons.
- Lesson 1: Students generate questions about the phenomenon to drive their learning and their design solutions (Teacher Edition, pages 46–47). The class then works together to develop a DQB that is revisited in lessons 4, 6, and 9.
- Lesson 2: “Use the Design Questions Board and Ideas for Investigations chart from Lesson 1 during this discussion to remind students of ideas they had and to add any new ideas. As ideas that are already listed on the Ideas for Investigations chart are talked about, note them, and as new ideas or more-specific ideas are surfaced, add those to the chart as well” (Teacher Edition, page 56).
- Lesson 4: The DQB is shared at the beginning of the lesson as students are prompted to think about other design questions. “What else do we need to figure out about the reaction system?” (Teacher Edition, page 125).
- Lesson 9: “Let’s take some time to revisit our questions on our DQB to see if we’ve answered any of our own questions” (Teacher Edition, page 229).

Students develop science ideas from **PS1.B: Chemical Reactions** to design their solutions to the unit engineering problem. For example:

- Lesson 2: Students reverse engineer an MRE to determine what type of chemical process is causing the MRE to heat up (Teacher Edition, page 50).
- Lesson 3: Students demonstrate their understanding of **PS1.B** by collecting data on several different chemical processes to determine what substances might work best for their device (Teacher Edition, page 93).
- Lesson 3: The class creates a particle-level reaction model and then adds energy transfer arrows to it to create an energy transfer model. These energy models support students in developing new learning of the **PS1.B** DCI.
- Lesson 4: "Let's think about the particle zoom-in piece of our model we discussed in Lesson 3. How are the particles different here than the way we did our experiment in Lesson 3? What changes when we change the proportion of reactants? There are different amounts of each reactant's particles in the reaction System. In Lesson 3, we figured out that increasing the total amounts of reactants while keeping the proportions the same in our system resulted in more energy transfer to the food system. How does changing the proportion of reactants affect this arrow? (Point at arrow coming out of reaction system to food system.) Say, How can we use these results to inform what amounts of reactants we use in our homemade flameless heaters?" (Teacher Edition, page 132). In this lesson students are taking what they learned about the chemical reactions they tested, and the energy produced by those reactions to make decisions concerning their solutions.

Suggestions for Improvement

None

I.B. THREE DIMENSIONS

Builds understanding of multiple grade-appropriate elements of the science and engineering practices (SEPs), disciplinary core ideas (DCIs), and crosscutting concepts (CCCs) that are deliberately selected to aid student sense-making of phenomena and/or designing of solutions.

i. Provides opportunities to *develop and use* specific elements of the SEP(s).

ii. Provides opportunities to *develop and use* specific elements of the DCI(s).

iii. Provides opportunities to *develop and use* specific elements of the CCC(s).

Rating for Criterion I.B. Three Dimensions	Extensive *(None, Inadequate, Adequate, Extensive)*

The reviewers found extensive evidence that the materials give students opportunities to build understanding of grade-appropriate elements of the three dimensions because students are regularly engaged in developing and using the targeted SEP, CCC, and DCI elements throughout the unit.

Science and Engineering Practices (SEPs) | **Rating: Extensive**

The reviewers found extensive evidence that students have the opportunity to use or develop the SEPs in this unit because students are regularly engaged with grade appropriate elements of the claimed SEPs in every lesson throughout the unit.

Asking Questions and Defining Problems

- *Ask questions that arise from careful observation of phenomena, models, or unexpected results, to clarify and/or seek additional information.*
  - Lesson 1: "There's a lot we need to figure out about the science of flameless heaters in addition to how to make a successful homemade flameless heater. Let's take a couple of minutes to write our questions so that they'll be clear to others when we want to get them organized. Look back at the questions you have in your Notice and Wonder chart, the questions you recorded during our modeling, and your initial design. What questions do you have about flameless heaters? What will we need to investigate in order to solve this problem? What else do we need to know to refine our criteria and constraints?" (Teacher Edition, page 46). This element is only used by students in this lesson; therefore, students may not have sufficient opportunities to fully use this element in the unit.
- *Define a design problem that can be solved through the development of an object, tool, process, or system and includes multiple criteria and constraints, including scientific knowledge that may limit possible solutions.*
  - Lesson 1: "Say, These flameless heaters and MREs are pretty useful, but they're not perfect. What problems or issues do you see with using MREs with flameless heaters to get hot food to people when they don't have their typical cooking methods available? Take a minute to jot down your ideas on the next clean page of your notebook" (Teacher Edition, page 37). In this lesson, students first define the problem, and then add more detailed criteria and constraints in later lessons.
  - Lesson 5: "Organize the criteria we need to consider for our design solutions. Draw students' attention to the initial Criteria and Constraints chart that was created in Lesson 1. Say, Now that we have a more-specific idea about the range of temperature to which food should be heated, we should update our list of criteria and constraints. But now, after looking at this chart, it seems like we have a lot of different ideas we are going to need to Consider" (Teacher Edition, page 146). Students use the scientific knowledge they gained from the articles they read about food temperatures and safety and revise their criteria and constraints for their designs based on the new information.
- *Ask questions to clarify and/or refine a model, an explanation, or an engineering problem.*
  - Lesson 9: "Discuss as a class the questions the class can now answer. Present slide U if needed. Pick a few questions that have the most dots and have the class discuss the answers to these questions as a group. If you have space, you might make a 'Take-Aways' board that has a record of the answers with which the class comes up. Encourage students to ask questions to help clarify the models the class has built so far. Work through these questions together to clear up the partial understandings" (Teacher Edition, page 229).

Engaging in Argument from Evidence

- *Make an oral or written argument that supports or refutes the advertised performance of a device, process, or system based on empirical evidence concerning whether the technology meets relevant criteria and constraints.*
    - This element is used in the Lesson 10 Sea Turtle Assessment but is not developed in the unit prior to the summative assessment. "Part 1. Evaluate an Existing Incubator: Incubator A This is an existing egg incubator available for purchase online. Will it work to move the sea turtle eggs? Review the advertised characteristics of this incubator below: Incubation temperature is adjustable. Heating element is above the eggs. Eggs are rotated on rotating disks. Humidity can be set for up to 85% relative humidity. Power supply is from a cord to an outlet. It holds up to 7 eggs. The cost is $200… Use the Design Testing Matrix to write an argument below that states whether incubator A will be sufficient to incubate sea turtle eggs effectively during relocation. Consider the criteria and constraints presented in the Design Testing Matrix and the advertised performance of incubator A in your argument" (Sea Turtle Assessment, pages 2–3).
- *Respectfully provide and receive critiques about one's explanations, procedures, models, and questions by citing relevant evidence and posing and responding to questions that elicit pertinent elaboration and detail.*
    - Lesson 7: Students share their how-to instructions and designs with other student teams. They provide constructive feedback about the designs and instructions about how well they fit the criteria and constraints.
- *Evaluate competing design solutions based on jointly developed and agreed-upon design criteria.*
    - Lesson 8: Students evaluate different design solutions in their groups based on the agreed-upon criteria and constraints developed by the class.

Developing and Using Models

- *Develop and/or use a model to predict and/or describe phenomena.*
    - Lesson 2: "Create a class consensus model. Use the Energy Transfer Model you created as reference and say, We could draw our cups around this thermometer and add our substance inside the cup and some arrows to show energy transfer, but that would be really messy. Instead, let's start a new model to make sure we can track the energy flow and see if we can use this to help with our homemade heater designs. Post a new piece of chart paper to begin the consensus model" (Teacher Edition, page 71).
    - Lesson 10: "Draw a model to explain 'How does the heat pack keep the turtle eggs warm?' Update the Energy Transfer Model to show how the energy is transferred between the reaction occurring in the heat pack and the incubator system containing the turtle eggs. Include a representation of what is happening to the substances that are undergoing the chemical reaction. Use the table below the Energy Transfer Model to explain what is happening at the scale we cannot see. Use the space in the table to draw a representation of what is happening to the substances that are undergoing the chemical reaction" (Sea Turtle Assessment, page 4).
- *Develop a model to describe unobservable mechanisms.*
    - Lesson 3: "Conduct a class discussion as the class builds a particle model of the reaction. Emphasize that we are just zooming in to the particles in the chemical reaction. Use the sample dialog below to guide the discussion as you build a particle model of the reaction so we can use it to figure out how energy interacts with our

systems. Ask students to draw the model in their notebook as you draw it on the board. Begin with the chemical reaction in a table similar to one we used in Bath Bombs Unit" (Teacher Edition, page 99).

- *Develop and/or revise a model to show the relationships among variables, including those that are not observable but predict observable phenomena.*
  - Lesson 3: "Assign student pairs to create their own Energy Transfer Models. Have student pairs copy in the first row of Energy Transfer Models the simple box model you just made on the board for the 1X reaction/1X food system. They should work with their partner to create a new Energy Transfer Model in the second row that would model the energy transfer from 2X the reactants to the same amount of food. They should be ready to share their results with the class in 5 minutes. Encourage them to use the model the class made together for the 1X reaction/1X food system as an example" (Teacher Edition, page 108). Students create models to show how the energy transfer in their system (unobservable) causes observable changes in the thermometer.
- *Develop or modify a model — based on evidence — to match what happens if a variable or component of a system is changed:*
  - Lesson 6: Students test their prototype models to test how well they work. They do not develop or modify the model to match what happens if a variable or component of the system is changed, however.

Constructing Explanations and Designing Solutions

- *Apply scientific ideas or principles to design, construct, and/or test a design of an object, tool, process, or system.*
  - Lesson 1: Students design their initial models of their solutions for the flameless heater using their prior knowledge about chemical reactions and energy.
  - Lesson 6: Students create their first model and prototype using what they have learned about chemical reactions and engineering design process and test it.
  - Lesson 9: Students create their final model using the results of data collected from testing their design earlier in the unit.
- *Undertake a design project, engaging in the design cycle, to construct and/or implement a solution that meets specific design criteria and constraints:*
  - This element is addressed throughout the unit as students design a flameless heater after experimenting with different possible reactants, identifying criteria and constraints, and designing several different iterations of their solution based on feedback.
  - Lesson 1: "Say, okay, so what criteria do we have for our homemade flameless heater? What does it need to be able to do? And what limitations will we have for our design? What constraints should we have? Turn and talk with a partner about that" (Teacher Edition, page 42).
  - Lesson 4: Students use the criteria and constraints to create a Stakeholder's Survey for the Flameless Heater.
  - Lesson 5: Students revisit their criteria and constraints of their design. "Say, now that we have a more-specific idea about the range of temperature to which food should be heated, we should update our list of criteria and constraints" (Teacher Edition, page 146).

  - Lesson 6: "Let's compare our list of ideas for investigations and our DQB with our Criteria and Constraints chart to make sure we aren't missing any other details or ideas we would need for our redesign" (Teacher Edition, page 167).
- *Optimize performance of a design by prioritizing criteria, making tradeoffs, testing, revising, and retesting:*
  - Lesson 8: In step 4 students produce a cascading consequences chart that shows their top ranked changes they want to make to their design and the consequences it will have.
  - Lesson 9: Students use their Consequences Chart, their Design Testing Matrix, and feedback from other groups to create their optimal Flameless Heater design.

Analyzing and Interpreting Data

- Analyze data to define an optimal operational range for a proposed object, tool, process, or system that best meets criteria for success.
  - Lesson 4: "Project or post the class data and have images of the filtered products available for students to see. …Then lead a Building Understandings Discussion to draw conclusions about the optimal proportion of reactants that results in the largest temperature change and what this means for our design solutions. Sample data are provided in Sample Data for Proportion of Reactants Investigation for your reference" (Teacher Edition, page 130). The class has a discussion based on their collected data about what proportions of reactant would be ideal for their heaters.
  - Lesson 5: Students use information and data found in articles and reading passages to determine the best temperature range for the food their flameless heater will be heating up.
  - Lesson 6: Students use data from testing their prototypes to determine how well it fits their criteria for success.

Planning and Carrying Out Investigations

- *Conduct an investigation and/or evaluate and/or revise the experimental design to produce data to serve as the basis for evidence that meets the goals of the investigation.*
  - Lesson 2: Students conduct an investigation as a class and collect data and observations concerning the temperature and mass of the heater over time in order to get data for their design solutions (Teacher Edition, pages 63–67).
- *Evaluate the accuracy of various methods for collecting data.*
  - Lesson 4: "Introduce a procedure that will be used for data collection. Say, I have a procedure we can use to collect these data, but I want your help to be sure that our methods will get us credible data with the fewest errors so that we can use it for making decisions later. Hand out Investigation Procedure for Proportion of Reactants and Analyzing Our Data Collection Methods. Display slide E. Say, If we want to figure out which combination of reactants, which proportion of each, is going to work the best for our reaction, then we need to trust our data. One way we can make sure our data are reliable is to check our procedures. We want to make sure our methods get us the data we need and that we are measuring our variables accurately and doing everything we can to reduce possible errors. Evaluate the first part of the procedure as a class. Read 'Part 1: Measuring Reactants' of the procedure together as a class. Then focus students' attention on Analyzing Our Data Collection Methods and solicit ideas

for the row for the first part of the procedure. Work together as a class to complete this first row of the table" (Teacher Edition, page 126).

- *Collect data to produce data to serve as the basis for evidence to answer scientific questions or test design solutions under a range of conditions:*
    - Lesson 3: "Record the data on chart paper as students suggest them. The minimum data that should be collected are as follows: amount of each substance (grams), starting temperature of substances (°C), temperature every 30 seconds for 5 minutes (°C), temperature change from starting to maximum or minimum temp (Δ°C), observations, such as any color changes, odors, how it feels when you touch the container, sounds. Prepare science notebooks to collect small-group data and assign chemical reactions to groups" (Teacher Edition, page 88). Students are collecting temperature data for different household chemical reactions to see which may have conditions favorable for their design solutions.
    - Lesson 4: Students collect data to determine the ratio of reactants that will best serve their Flameless Heater.
    - Lesson 6: Students collect data about their prototype and how it is working towards the criteria and constraints of the problem.
    - Lesson 8: Students use collected data and peer reviews to figure out what the impacts of their changes will be.
    - Lesson 9: Students use the collected data from Lessons 3, 6, and 8 as reasoning for why they chose the specifications they did for their final design.

Obtaining, Evaluating, and Communicating Information

- *Communicate scientific and/or technical information (e.g., about a proposed object, tool, process, system) in writing and/or through oral presentations.*
    - Lesson 9: "Distribute copies of How-to Instructions Must-Haves and remind teams to review and use the following as they revise their instructions: the partner team sticky note feedback they received on How-to Instructions Must-Haves in Lesson 7, their Consequences Chart from Lesson 8, their Stakeholder Impact Chart from Lesson 8, and their Design Testing Matrix… Say, Though Design Must-Haves and How-to Instructions Must-Haves are very similar, we have to remember which pieces are important to us and which pieces are important to someone building our designs. Follow How-to Instructions Must-Haves to make sure we have everything we need for our instructions. Walk around the room and check that each team completes their How-to Instructions. Make sure that teams are also completing question 2 in How-to Instructions Must-Haves about how they have improved their instructions" (Teacher Edition, page 223). Students write their How-to Instructions in small groups to communicate how to build their homemade flameless heaters.
- *Critically read scientific texts adapted for classroom use to determine the central ideas and/or obtain scientific and/or technical information to describe patterns in and/or evidence about the natural and designed world(s).*
    - Lesson 5: Students are provided different articles in jigsaw groups. Students are instructed to find the main ideas and obtain information about food temperature range to share with their groups. While these articles come from scientifically accurate sources, they are not scientific texts adapted for classroom use.

Using Mathematics and Computational Thinking

- *Apply mathematical* concepts and/or processes (e.g., ratio, rate, percent, basic operations, simple algebra) to scientific and engineering questions and problems.
    - Lesson 4: "Say, How can we use these results to inform what amounts of reactants we use in our homemade flameless heaters? When we investigated the proportion of reactants, we used a total of six grams of reactants. What if we want to use more than six grams of reactants? How can we scale this up but keep the same proportion so that none of the reactants are left over? Calculate the optimal amount of each reactant used in terms of percent of the total reactants" (Teacher Edition, page 132).
    - Lesson 6: "Teams may choose to calculate the amounts of reactants they use in one of two ways. In either case, they will want to use the most efficient proportion as found in Lesson 4. If they have a total mass in mind for the reactants that they want to use in their design, they may find the percentages of that mass for aluminum (8%) and copper sulfate (92%). Or, since they figured out in Lesson 4 that 0.5 grams of aluminum and 5.5 grams of copper sulfate were the most efficient amounts, they may choose to scale up that amount by doubling, tripling, and so forth" (Teacher Edition, page 172).

Disciplinary Core Ideas (DCIs) | **Rating: Extensive**

The reviewers found extensive evidence that students have the opportunity to use or develop the DCIs in this unit because students are engaged with the targeted DCIs (listed on the Unit Overview, page 1, of the Teacher Edition) throughout the unit. Some examples of evidence are provided below:

PS1.B Chemical Reactions

- *Some chemical reactions release energy, others store energy.*
    - Lesson 1: "I'll give you a blank piece of paper where you can plan your design—use words and drawings to help get your ideas onto paper. Be sure that your design shows how your heater will cause food to be heated up. We'll work for about five minutes before we share our design in small groups" (Teacher Edition, page 43). In this lesson students make their initial design and think about what might be causing the food to heat up.
    - Lesson 2: In groups, students complete an investigation that provides evidence that a chemical reaction has occurred.
    - Lesson 3: Students perform various chemical reactions and then discuss which raised the temperature of the surrounding system and which lowered the temperature. The concepts of exothermic and endothermic are discussed (Teacher Edition, pages 93–95).
    - Lesson 4: Students test different amounts of aluminum and $CuSO_4$ to see which release the most energy within the constraints of their design.

ETS1.A: Defining and Delimiting Engineering Problems

- *The more precisely a design task's criteria and constraints are defined, the more likely it is that the designed solution will be successful. Specification of constraints includes consideration of scientific principles and other relevant knowledge that is likely to limit possible solutions.*
    - Lesson 1: The class defines criteria and constraints and then discusses what the criteria for success for their heaters should be and what logical constraints there should be for the heaters (Teacher Edition, pages 41–43).

- Lesson 5: Students redefine their criteria and constraints to make them more specific and include what they have learned so far and the survey responses they have received from the stakeholders (Teacher Edition, pages 146–148).
- Lesson 6: Students use the criteria and constraints to design their heaters.
- Lesson 7: Student teams share designs to help to determine which flameless heater design characteristics are more promising than others with respect to the identified criteria and constraints.

ETS1.B: Developing Possible Solutions

- *Models of all kinds are important for testing solutions.*
    - Lesson 6: Students are asked to discuss why it is important to have both models on paper and physical models for their design (Teacher Edition, page 170).
    - Lesson 9: After students build and test another design, discussion occurs about how each of their different models (paper and prototype) is helping them plan and test their proposed designs.
- *There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem.*
    - Lesson 8: Students use the idea of "cascading consequences" to think about how the changes they are making to address the criteria and constraints of the problem would affect the whole design.
- *Sometimes parts of different solutions can be combined to create a solution that is better than any of its predecessors.*
    - Lesson 7: Teams gather in an Engineer's Circle to share their designs. As a class, a chart is created to record the most promising design characteristics.
    - Lesson 8: Teams select any design characteristics from the class chart they want to incorporate into their own design.

ETS1.C: Optimizing the Design Solution

- *The iterative process of testing the most promising solutions and modifying what is proposed based on the test results leads to greater refinement and ultimately to an optimal solution.*
    - Lesson 6: Students redesign their Flameless Heater from their initial model created in Lesson 1 after performing investigations in Lessons 2, 3, and 4 to determine the most promising chemical reaction for their design.
    - Lesson 6: Students build and test their designs and evaluate its success.
    - Lesson 7: Students share their designs and test results with other groups to continue to refine their design.
    - Lesson 9: Students create their optimal design for the Flameless Heater.
- *Although one design may not perform the best across all tests, identifying the characteristics of the design that performed the best in each test can provide useful information for the redesign process — that is, some of the characteristics may be incorporated into the new design.*
    - Lesson 7: Students participate in an Engineers Circle using their Design Testing Matrix. As a class, they create a chart describing the most promising design characteristics from each team. In subsequent lessons, students are encouraged to incorporate these characteristics into their teams' design.

Crosscutting Concepts (CCCs) | **Rating: Extensive**

The reviewers found extensive evidence that students have the opportunity to use or develop the CCCs in this unit because students frequently engage with the grade appropriate elements of **Systems and System Models**, and **Energy and Matter**. However, elements from **Cause and Effect** and **Patterns** are claimed in many lessons but students are not engaging with these CCCs at the middle school element level in all of the claimed lessons.

Cause and Effect

- *Cause and effect relationships may be used to predict phenomena in natural or designed systems:*
    - This element is claimed in Lesson 1, but teacher and student prompts do not indicate that students are engaged with the concept of **Cause and Effect**.
    - Lesson 8: "Even if everyone on the team agrees on the changes you want to make, do we know for sure that these are the best decisions? Have we considered all of the consequences that will result from the changes we want to make? Display slide F and add a piece of blank chart paper to the wall and label It "Consequences Chart." Say, Getting really organized and being systematic about keeping track of how one change will affect other criteria or constraints will be important to be confident about the decision we make. We can design a Consequences Chart to keep track of these changes and what happens as a result" (Teacher Edition, page 203). Students develop a consequences chart to track how changes to their design will cause other effects in its performance.

Patterns

- *Graphs, charts, and images can be used to identify patterns in data.*
    - This CCC element is claimed in Lessons 4 and 5 but is only interacted with on the large-scale level and not at a grade-appropriate element level. While patterns are mentioned in some of the teacher notes, language from the elements of this CCC is absent from student prompts in these lessons.
- *Patterns can be used to identify cause and effect relationships.*
    - This CCC element is claimed in lesson 7 but is only interacted with on the large-scale level and not at a grade-appropriate element level. Language from the elements of this CCC is absent from student prompts in this lesson.

Systems and System Models

- *Models can be used to represent systems and their interactions — such as inputs, processes, and outputs — and energy and matter flows within the system.*
    - Lesson 1: Students make an initial model describing "How does a flameless heater work to heat food?"
    - Lesson 3: "As you monitor groups, ask questions to help students focus on what they are trying to figure out rather than just focusing on the procedures. Here are example questions you might ask: What are you noticing about the temperature change? How do you think energy is transferring in this reaction? If you think about two systems involved, the reaction system and the thermometer, what direction is the energy transferred to make the temperature increase or decrease?" (Teacher Edition, page 89).

- Lesson 3: "Shift focus to considering energy in the reaction. Display slide R. Now that students understand the particles involved in the copper sulfate and aluminum reaction, help them shift to thinking about what is happening with the energy during an exothermic reaction. Use the example dialogue as you add to the class model…Add energy ideas to the model. Continue working with the class to add these energy ideas to the model. Have students consider each system that is represented in their investigation. The reaction system has more than just the copper sulfate and the aluminum; it also includes the saltwater. The chemical reaction is a subsystem of the reaction system. The surroundings outside the reaction system that we are most interested in is the food system since that is the energy transfer we want to maximize" (Teacher Edition, page 103).
- Lesson 3: "Begin a model to track the energy transfer between these systems.✱ Direct students' attention to the model you ended with in the last class. Say, When scientists and engineers are trying to figure something out, they often think about the systems involved. They identify the parts of the systems and how those parts work together. Our chemical reaction is a subsystem of the reaction system--it is part of the whole reaction system. Let's shift our focus from the very small, particle-level models to the larger, system-level views to think about energy. Continue the discussion by connecting to work engineers do by identifying systems and subsystems, how the MRE has systems and subsystems, and how now we will shift from thinking about the interacting particles in the copper sulfate and aluminum reaction to the energy transfer from that reaction. We will focus on the reactions we tested on the first day of this lesson. Tell students we will focus on only the 1.0-g and 2.0-g systems since we have already established the pattern that as the amount increases, so does the temperature" (Teacher Edition, page 106).
- Lesson 6: "Use the model to show: how the energy will be transferred from the reaction system to the food and what is happening to the food when this energy is transferred to it (you may use zoom-ins to show particle motion)" (Lesson 6 Design Model Must-Haves).
- Lesson 9: "Use the model to show: how the energy will be transferred from the reaction system to the food and what is happening to the food when this energy is transferred to it (you may use zoom-ins to show particle motion)" (Lesson 9 Design Model Must-Haves).
- Lesson 10: "Draw a model to explain "How does the heat pack keep the turtle eggs warm?" Update the Energy Transfer Model to show how the energy is transferred between the reaction occurring in the heat pack and the incubator system containing the turtle eggs. Include a representation of what is happening to the substances that are undergoing the chemical reaction. Use the table below the Energy Transfer Model to explain what is happening at the scale we cannot see. Use the space in the table to draw a representation of what is happening to the substances that are undergoing the chemical reaction" (Sea Turtle Assessment, page 4).

* *Systems may interact with other systems; they may have sub-systems and be a part of larger complex systems.*
  - Lesson 2: Students create an energy transfer model that includes the chemical reaction system and the food system. Both of these systems are included in the larger heater system.

- Lesson 3: The teacher is prompted to say "When scientists and engineers are trying to figure something out, they often think about the systems involved. They identify the parts of the systems and how those parts work together. Our chemical reaction is a subsystem of the reaction system--it is part of the whole reaction system. Let's shift our focus from the very small, particle-level models to the larger, system-level views to think about energy" (Teacher Edition, page 106).

Energy and Matter

- *The transfer of energy can be tracked as energy flows through a natural system:*
    - Lesson 1: "While we might not know everything yet about how flameless heaters work, we can still refer to the classroom consensus model along with our Criteria and Constraints chart to help inform us in modeling a design solution. I'll give you a blank piece of paper where you can plan your design—use words and drawings to help get your ideas onto paper. Be sure that your design shows how your heater will cause food to be heated up" (Teacher Edition, page 43). Students are making their initial design and giving a basic initial model for the energy flow in their design.
    - Lesson 2: The class tracks the energy flow in a system of water and a thermometer using models showing the energy flow in the system (Teacher Edition, pages 58–62).
    - Lesson 3: "As you monitor groups, ask questions to help students focus on what they are trying to figure out rather than just focusing on the procedures. Here are example questions you might ask: What are you noticing about the temperature change? How do you think energy is transferring in this reaction? If you think about two systems involved, the reaction system and the thermometer, what direction is the energy transferred to make the temperature increase or decrease?" (Teacher Edition, Page 92).
    - Lesson 3: "Shift focus to considering energy in the reaction. Display slide R. Now that students understand the particles involved in the copper sulfate and aluminum reaction, help them shift to thinking about what is happening with the energy during an exothermic reaction. Use the example dialogue as you add to the class model…Add energy ideas to the model. Continue working with the class to add these energy ideas to the model. Have students consider each system that is represented in their investigation. The reaction system has more than just the copper sulfate and the aluminum; it also includes the saltwater. The chemical reaction is a subsystem of the reaction system. The surroundings outside the reaction system that we are most interested in is the food system since that is the energy transfer we want to maximize" (Teacher Edition, page 103).
    - Lesson 9: "The following information must be clearly shown in your model, and your teacher must approve this model before you begin construction on your prototype… Use the model to show how the energy will be transferred from the substances in the reaction system to the food (and how it has been improved since the previous design) and what is happening to the food when this energy is transferred to it (you may use zoom-ins to show particle motion)" (Design Model Must-Haves Handout).
    - Lesson 10: "Draw a model to explain "How does the heat pack keep the turtle eggs warm?" Update the Energy Transfer Model to show how the energy is transferred between the reaction occurring in the heat pack and the incubator system containing the turtle eggs. Include a representation of what is happening to the substances that are undergoing the chemical reaction. Use the table below the Energy Transfer Model

to explain what is happening at the scale we cannot see. Use the space in the table to draw a representation of what is happening to the substances that are undergoing the chemical reaction." (Sea Turtle Assessment, page 4)

- *Within a natural system, the transfer of energy drives the motion and/or cycling of matter*.
    - Lesson 6: "Let's think about the particle zoom-in piece of our model we discussed in Lesson 3. How are the particles different here than the way we did our experiment in Lesson 3? What changes when we change the proportion of reactants?... What to look for and listen for: Teams' designs should include all the characteristics listed on Design Must-Haves regarding criteria and constraints and also a sketch showing the particles of the substances in the flameless heater reaction colliding with particles of the container(s) and the food to show how that transfer of energy happens. food)… If a team's design does not include the energy transfer at the particle level, it may be helpful to refer to the initial consensus model you made as a class in Lesson 1 that shows how the MRE heater's particles were moving and ask the team to consider how that might be similar to their design. If these students experienced OpenSciEd Unit 6.2: How can containers keep stuff from warming up or cooling down? (Cup Design Unit), referring to the models they drew of the energy transfer happening with their cups may also be helpful" (Teacher Edition, pages 172–173).

Stability and Change

- *Small changes in one part of a system might cause large changes in another part*.
    - Lesson 8: Students develop a "Cascading Consequences" chart to show how making a change according to their stakeholder surveys might cause other effects/changes that could change the performance of their device.

Suggestions for Improvement

Crosscutting Concepts

Ensure that students are engaging with the CCC of **Patterns** at the element level. Consider using language from the elements in student prompts so students recognize that they are engaging with these CCC elements.

I.C. INTEGRATING THE THREE DIMENSIONS

Student sense-making of phenomena and/or designing of solutions requires student performances that integrate elements of the SEPs, CCCs, and DCIs.

Rating for Criterion I.C. Integrating the Three Dimensions	Extensive *(None, Inadequate, Adequate, Extensive)*

The reviewers found extensive evidence that student performances integrate elements of the three dimensions in service of figuring out phenomena and/or designing solutions to problems because there are numerous events where students use all three dimensions to figure out the flameless heater phenomenon and solve the problem of a better homemade flameless heater. Rarely do dimensions appear in isolation in the lessons and student tasks regularly integrate two or three dimensions together.

Related evidence includes:

- Lesson 1: Students create their initial model of what is happening inside the flameless heater at different scales before and after water is added. In this performance, students integrate the following elements:
  - SEP: *Develop and/or use a model to predict and/or describe phenomena.*
  - CCC: *Phenomena that can be observed at one scale may not be observable at another scale*
  - DCI: **PS3.B Conservation of Energy and Energy Transfer**
- Lesson 2: The class participates in conducting an investigation of temperature changes in a flameless heater-water-cup system. The class discusses energy transfer from the heater to the water to the thermometer as they design and revise the experiment with the teacher. In this performance, students integrate the following elements:
  - SEP: *Conduct an investigation … to produce data to serve as the basis for evidence that meet the goals of the investigation*.
  - CCC: *The transfer of energy can be tracked as energy flows through a natural system*.
  - DCI: **PS3.B Conservation of Energy and Energy Transfer**
- Lesson 3: "Assign student pairs to create their own Energy Transfer Models. ... They should work with their partner to create a new Energy Transfer Model in the second row that would model the energy transfer from 2X the reactants to the same amount of food. They should be ready to share their results with the class in 5 minutes. Encourage them to use the model the class made together for the 1X reaction/1X food system as an example. Say, 'Your model should explain what you predict will happen to the temperature compared to the temperature of the original reaction and food systems. Color your thermometer to show how it would compare to the reaction system in the first row. Use the size of the arrows to communicate the amount of energy flow'" (Teacher Edition, page 108). In this activity, students integrate the following elements:
  - SEP: *Develop a model to describe unobservable mechanisms.*
  - CCC: *Develop a model to describe unobservable mechanisms.*
  - DCI: **PS3.B Conservation of Energy and Energy Transfer**.
- Lesson 6: "Allow teams the rest of today's class period to work on their designs. Display slide L. Provide access to scales, containers, building materials, … and Materials Cost List so that students can explore how these materials could be used in their designs and find out their masses in order to meet that constraint. As they work, circulate and check in, especially paying attention to the amounts of reactants that teams are planning to use. If you do not get to check each team's plan for reactants today, you will want to be sure to do that before they begin building…What to look for and listen for: Teams' designs should include all the characteristics listed on Design Must-Haves regarding criteria and constraints and also a sketch showing the particles of the substances in the flameless heater reaction colliding with particles of the container(s) and the food to show how that transfer of energy happens" (Teacher Edition, pages 172–173). In this activity, students integrate the following elements:

  - SEP: *Undertake a design project, engaging in the design cycle, to construct and/or implement a solution that meets specific design criteria and constraints.*
  - CCC*: The transfer of energy can be tracked as energy flows through a natural system.*
  - DCI: **PS3.B Conservation of Energy and Energy Transfer**.
- Lesson 8: "Give directions for the Discussion Diamond protocol. Display slide C. Say, In a moment, we will share our ideas with the rest of our team. To make it easy to compare ideas and give each person a chance to speak, we will use the Discussion Diamond protocol. … After everyone has shared their justifications, begin round 2. In round 2, the purpose is to come to a consensus about which 2-3 things your team wants to modify for the final homemade heater design. The whole team has a chance to talk freely with each other, to ask questions to specific team members, and to add any ideas you may have thought of as other team members presented their ideas. Keep your Design Testing Matrix out as well, and use the information there to support your ideas during the discussion. The goal is for your team to be in agreement about which 2-3 elements to change by the end of this discussion. Record these 2-3 things in the middle of the handout" (Teacher Edition, page 201). Then, after deciding on their changes, students use a Cascading Consequences Chart to determine how changing one thing about their design could cause other factors to change as well. In this performance, students integrate the following elements:
  - SEP: *Evaluate competing design solutions based on jointly developed and agreed-upon design criteria*.
  - CCC: *Small changes in one part of a system might cause large changes in another part*.
  - DCI: **ETS1.C: Optimizing the Design Solution** — *Although one design may not perform the best across all tests, identifying the characteristics of the design that performed the best in each test can provide useful information for the redesign process — that is, some of the characteristics may be incorporated into the new design*.
- Lesson 10: "2b. Draw a model to explain 'How does the heat pack keep the turtle eggs warm?' Update the Energy Transfer Model to show how the energy is transferred between the reaction occurring in the heat pack and the incubator system containing the turtle eggs. Include a representation of what is happening to the substances that are undergoing the chemical reaction. Use the table below the Energy Transfer Model to explain what is happening at the scale we cannot see. Use the space in the table to draw a representation of what is happening to the substances that are undergoing the chemical reaction" (Sea Turtle Assessment, page 4). In this performance, students integrate the following elements:
  - SEP: *Develop a model to describe unobservable mechanisms.*
  - CCC: *Models can be used to represent systems and their interactions — such as inputs, processes, and outputs — and energy and matter flows within systems.*
  - DCI: **PS3.B Conservation of Energy and Energy Transfer**.
- Lesson 10: "3c. For the criterion of temperature, how would you optimize the design using the chemical reaction in incubator B in order to ensure the hatching of male sea turtles? You may choose to increase, decrease, or keep the same amount of reactants in your redesign. It is not necessary to include the exact amounts of reactants used. In your response, update the Energy Transfer Model you made for question 2b to explain why your redesign will work. Include a caption that addresses the changes you made and the effect those changes had on the energy transfer between parts of the system…3d. Beyond temperature, which additional characteristics from each design would you use in your optimal design? To do this, go through each criterion and constraint and state your reasons (including discussion of how energy is

transferred) for which design (incubator A or B) you would choose for that characteristic" (Sea Turtle Assessment, pages 6–7). In this performance, students integrate the following elements:

- SEP: *Apply scientific ideas or principles to design, construct, and/or test a design of an object, tool, processs, or system*.
- CCC: *The transfer of energy can be tracked as energy flows through a natural system*.
- DCI: **ETS1.B: Developing Possible Solutions**.

Suggestions for Improvement

None

I.D. UNIT COHERENCE

Lessons fit together to target a set of performance expectations.

i. Each lesson builds on prior lessons by addressing questions raised in those lessons, cultivating new questions that build on what students figured out, or cultivating new questions from related phenomena, problems, and prior student experiences.

ii. The lessons help students develop toward proficiency in a targeted set of performance expectations.

Rating for Criterion I.D. Unit Coherence	Extensive *(None, Inadequate, Adequate, Extensive)*

The reviewers found extensive evidence that lessons fit together coherently to target a set of performance expectations because the problem presented for students to solve creates a thematic linkage across the unit such that students see explicit connections between lessons. The DQB, Ideas for Investigations, What we do as Engineers Board, and the Progress Tracker help to connect lessons together and make students aware of how prior learning is connected with current learning and future learning. Throughout the unit students are developing proficiency for a targeted set of performance expectations.

The DQB is developed in Lesson 1 and used to develop a list of "Ideas for Investigations" that students could do throughout the unit. Students return to see what questions have been answered or that they could now answer in Lessons 4, 6, and 9. However, no new questions are added to the DQB during the unit. The "Ideas for Investigation" list is updated and referred to a few times in the unit. Related evidence includes:

- Lesson 1: "Direct students to bring their questions on sticky notes to the circle. Say, We have a lot of really helpful questions that will direct our work. It is important that we hear everybody's questions, and we might find that we have questions similar to some of our classmates' questions. We are going to create a Design Questions Board (yes, you heard me right—it's still a DQB, but a little different for this unit since we're focused on this design work). We want to group and organize our questions so that they can help guide our investigations and keep track of what we want to figure out" (Teacher Edition, page 47).

- Lesson 1: “Say, We have so many questions to explore! How could we start to investigate the answers to some of these questions? Title the next page in your science notebook ‘Ideas for Investigations.’ Choose one question or category of questions from our Design Questions Board and talk with one or two people near you to consider how we might find the answer—what investigation could we design, what data should we gather, and how could we figure this out in our classroom? Keep track of your ideas in your notebook. After you’ve discussed one question, move on to another. We’ll work for about five minutes” (Teacher Edition, page 49).
- Lesson 4: “Navigate to today’s work. Display slide A and make sure that the DQB is visible. (*Slide A asks students to think about what else they still need to figure out in order to make a homemade flameless heater)* ‘Say, Last time, we figured out that mixing copper sulfate and aluminum foil together transferred a lot of energy out of the reaction system.... What else do we need to figure out about the reaction system in order to create a homemade flameless heater?’” (Teacher Edition, page 125). Here students orally discuss what other questions need to be answered in order for them to make their own flameless heater.
- Lesson 6: “Revisit our DQB and Ideas for Investigations chart to mark off what we have accomplished. Display slide B and give every student one sticky note. Direct students to write a check mark on the sticky note and then come up to the Design Questions Board and/or Ideas for Investigations chart and attach their sticky note near a question or investigation idea that the class has already completed. This is meant to be a quick trip to the charts and sit back down—no deliberation needed. If someone else has already put a sticky note where they had planned to, the student can add their sticky note on top of that one or find another question or investigation that has been completed” (In this performance, students integrate the following elements: page 166).
- Lesson 9: “Direct students to our Design Questions Board to reflect on what we’ve accomplished. Say, Wow, we’ve figured out so many different pieces to help answer our big question, ‘How can we help people design a flameless heater?’ Let’s take some time to revisit our questions on our DQB to see if we’ve answered any of our own questions. Work in pairs to evaluate what questions the class has answered from the DQB. Display slide S. Provide students with Questions from Our DQB, which you created to contain all of the student questions from the DQB and have students tape it into their science notebooks. Have pairs of students work to mark questions they think the class has answered. We did not answer this question or any parts of it yet: O   Our class answered some parts of this question, or I think I could answer some parts of this question: ✓ Our class answered this question, or using the ideas we have developed, I could now answer this question: ✓+” (Teacher Edition, page 229).

The Progress Tracker is used throughout the unit to help students record their thoughts on what engineers do and ideas about the engineering process. This tracker is used and reviewed in every lesson. Some examples are listed below:

- Lesson 1: “Say, Like in past units, our Progress Tracker will be a tool in our science notebooks to keep track of ideas we figure out to work on answering a question. However, in this unit, our question is about solving a problem: How can we design a homemade flameless heater? To help us keep track of what we’ve figured out about this designing-solutions work (called engineering), we will use different column headings than we have had in other units. Tell students, The left-side column heading is “What did we do as engineers?” and the right-side column heading is “What did we figure out that can help us with our designs?” Go ahead and set this T-chart up in your notebook. Depending on the task on which they are reflecting, sometimes students will complete the tracker independently and sometimes with more scaffolding as a class. Use questions, such as those that follow, to guide students as they make their first entries in this new tracker" (Teacher Edition, page 39).

- Lesson 2: "Update Progress Trackers. Display slide S. Direct students to the Progress Tracker section of their science notebook. Use questions similar to the following to help students process the lesson's work and record their thinking" (Teacher Edition, page 76).
- Lesson 3: "Have students go to the Progress Tracker section of their science notebook. Use questions like those below to help students process their work and record their thinking. Highlight important ideas and encourage students to put them in their Progress Trackers. The example shows some ideas that may surface… Think back to what we just accomplished. What did we do in the last couple of days to figure out what is going on in our chemical reactions? Why was drawing models of this important for our work?" (Teacher Edition, page 115).
- Lesson 4: "Direct students to the Progress Tracker section of their science notebook. Ask students what part of our What We Do as Engineers board we have been working on. Listen for students to say, "systematically testing parts of our design solution." Ask students to add what they have figured out through that systematic testing on the right side of their Progress Tracker" (Teacher Edition, page 134).
- Lesson 5: "Remain in the Engineers Circle and direct students to the Progress Tracker section of their science notebook. Display slide I. Say, Great! This is a big step—we just refined the criteria and constraints for our design. Let's add this to our Progress Tracker and our What We Do as Engineers board" (Teacher Edition, page 150).
- Lesson 10: "Say, Let's pull out our Progress Trackers, talk with a partner about any new ideas we recorded on our Progress Trackers, and ask our partner any final questions we have before we demonstrate our learning on a final assessment. Compare your Progress Tracker with our Design Questions Board, did we leave any big questions unanswered? Did any new big questions arise from what we figured out in this unit? Give students 3-5 minutes to talk with a partner about the questions on slide B. 1. What new ideas or insights did you add to your Progress Tracker? 2. What remaining questions do you have? Answer any remaining questions that students have as a whole class. Allow students to ask in a whole-class discussion any final questions that are unresolved. Answer questions with the class as time allows" (Teacher Edition, page 235).

There are some examples of student ideas and questions driving the learning into the next lesson:

- Lesson 2: "Use the Design Questions Board and Ideas for Investigations chart from Lesson 1 during this discussion to remind students of ideas they had and to add any new ideas. As ideas that are already listed on the Ideas for Investigations chart are talked about, note them, and as new ideas or more-specific ideas are surfaced, add those to the chart as well" (Teacher Edition, page 56).
- Lesson 4: "Show slide R and have students turn and talk with a partner about what questions they would find useful to ask a stakeholder. Say, It seems like we've identified who our stakeholders will be for our designs. We had some thoughts about what might be important to them, but how can we be sure? Is there a way we can really find out what's most important to them? What questions would you ask? Gather and refine questions to ask stakeholders. Conduct a brief discussion to compile questions to create a Stakeholder Survey specific to your classes. Say, You all have some great ideas! Let's get these ideas out on the table and then we can create a survey that we can use with our stakeholders" (Teacher Edition, page 137).

- Lesson 5: "Reflect on the Stakeholder Survey conducted in Lesson 4 and consider what else we need to know to inform our designs" (Teacher Edition, page 140).
- Lesson 5: "Show slide B. Say, Based on our last discussion, it seems like these are the three main questions we think we need to answer in order to define our target temperature range. 1. What temperature is too hot? 2. Does food need to get to a certain temperature to avoid illness? 3. How warm does food need to get for people to enjoy the taste? Underline or use arrows to highlight important information in your reading and then tag it using these symbols to note which question the information is helping us answer. Add any other notes or questions you have as well" (Teacher Edition, page 144).
- Lesson 6: "Turn and talk with a neighbor about what information you still need before you're ready to try a redesign. After about 2 minutes of partner talk, invite students to share their thoughts. As they do, use sticky notes or markers to note on the Criteria and Constraints chart the parts for which we still need more information. (See example image shown here, with new notes added in a lighter blue.) Students will likely point out the need for detail around the following: mass (e.g., What materials can we use to build our homemade heater? How will they fit our criterion for total mass?), cost (e.g., How much will our heater materials cost?), instructions (e.g., How can we make our flameless heaters easier to use?), time (e.g., How long will our heaters take to work?), food substitute (e.g., If we can't have food in the classroom, what will we use instead?) Say, OK, so we need to spend a little more time thinking about these ideas and details to help us meet our criteria and constraints before we're ready to begin our redesigns" (Teacher Edition, page 167).

The lessons help students build proficiency in the targeted PEs while creating a solution for the flameless heater. The engineering PEs, **MS-ETS1-2**, **MS-ETS1-3**, and **MS-ETS1-4** are used in tandem with **MS-PS1-6** throughout the unit as students develop models of the MRI flameless heater and how it works and design their own homemade flameless heater that is less expensive and fits their criteria and constraints.

Suggestions for Improvement

Allow opportunities in each lesson for students to cultivate new questions about the phenomenon or problem based on their new learning. This will allow opportunities for students to feel that their questions are driving the learning and engage students in the SEP of **Asking Questions** beyond lesson 1.

I.E. MULTIPLE SCIENCE DOMAINS

When appropriate, links are made across the science domains of life science, physical science and Earth and space science.

i. Disciplinary core ideas from different disciplines are used together to explain phenomena.

ii. The usefulness of crosscutting concepts to make sense of phenomena or design solutions to problems across science domains is highlighted.

Rating for Criterion I.E. Multiple Science Domains	Adequate *(None, Inadequate, Adequate, Extensive)*

The reviewers found adequate evidence that links are made across the science domains when appropriate because the unit phenomenon and problem can be explained and solved within the single domain of physical science. However, the usefulness of CCCs to make connections across science domains is not mentioned in these lessons.

Both explaining the phenomenon of how a flameless heater works and designing a solution to the problem of a cheap, homemade, flameless heater only require students to understand and use DCI from **PS1 Chemical Reactions** and **PS3 Energy** as students study different chemical reactions that could produce heat and track the flow of energy in the flameless heater-food system.

Suggestions for Improvement

- Consider using CCCs such as **Systems and System Models** and **Energy and Matter** to connect learning to other science domains students have previously studied.
- A connection to **ESS3.B Natural Hazards** may allow students to connect locations of natural hazards to where the new flameless heaters would most likely be needed. There is potential for this DCI to be incorporated in Lesson 1 when students are identifying events that would cause a need for flameless heaters.

I.F. MATH AND ELA

Provides grade-appropriate connection(s) to the Common Core State Standards in Mathematics and/or English Language Arts & Literacy in History/Social Studies, Science and Technical Subjects.

Rating for Criterion I.F. Math and ELA	Extensive *(None, Inadequate, Adequate, Extensive)*

The reviewers found extensive evidence that the materials provide grade-appropriate connections to the Common Core State Standards (CCSS) in mathematics, English language arts (ELA), history, social studies, or technical standards because the teacher materials explicitly state mathematics and ELA standards that are used in the unit and provide support in the materials for students to see connections between content areas. Additionally, students regularly use speaking and listening skills in a variety of formats and writing skills to communicate their understanding of the flameless heater phenomenon.

Some examples of students using reading skills, writing skills, speaking skills, and listening skills during the unit include:

- Lesson 1: “Say, In a moment, we will gather in small groups and share our designs. In order to be sure everyone gets a chance to speak, we will use our writing utensils as “talking sticks.” To begin round 1, everyone in the group will put their writing utensil into the center of the group. As each person takes a turn to tell the group about their design, they pick up their writing utensil. No one gets to respond to the person explaining their design during round 1—each person is only telling about their design. After all the writing utensils have been picked up, place them in the middle again to begin round 2. In round 2, each person will have a chance to comment on similarities and differences between their design and others or they can ask clarifying questions about others designs. As each person shares they are to pick up their writing utensil when they do so. If a person responds to a question during round 2, that does not count as their comment and they do not pick up their writing utensil until they have initiated a question or comment themselves" (Teacher Edition, page 44).

- Lesson 3: "Ask students to complete the model using the same conventions. Tell them to write a short statement of what happens to the particles when they react and put it in the middle column. Then ask them to share with their elbow partner and make revisions if they learn something from their partner" (Teacher Edition, page 100).
- Lesson 3: "Display slide T. Students should work with a partner to draw their Energy Transfer Models in the first and second rows of Energy Transfer Models. Students may want to use a pencil, especially to shade the thermometer, so that if the data do not support their prediction, they can erase and revise their model. Tell students that they should both be able to use their models to explain energy transfer between the 2X reaction system and the 1X food system. Monitor student conversations and identify one model to display. While students are working, circulate among them to identify one or two models that will be productive examples to share with the class. They do not need to be perfect because we want to foster an environment where it is safe to share first-draft thinking, but choose models that will be good starting points for discussion in the next step. Be sure to confirm with the partners that they are willing to share their work with the class" (Teacher Edition, page 108).
- Lesson 4: In part 1, students are asked to "Turn and talk with an elbow partner and discuss what we should do as our next steps if we want to help people make homemade heaters to warm up their food. What else do we need to figure out about the reaction system?" (Teacher Edition, page 125). Students then share their ideas with the whole class.
- Lesson 4: "Discuss how we can figure out stakeholder preferences. Show slide R and have students turn and talk with a partner about what questions they would find useful to ask a stakeholder. Say, It seems like we've identified who our stakeholders will be for our designs. We had some thoughts about what might be important to them, but how can we be sure? Is there a way we can really find out what's most important to them? What questions would you ask?" (Teacher Edition, page 137).
- Lesson 5: "Organize students into groups of 3 and distribute the readings. Reading: How hot does food need to get so that people do not get sick?, Reading: What temperatures cause scald burn injuries?, and Reading: What temperature range makes food enjoyable to eat?. Assign each member one of the readings and instruct them that they are responsible for reading and reporting on that resource to their group. Remind students that the purpose of this reading is to figure out the temperature range at which we want the food heated by our homemade heaters to be" (Teacher Edition, page 144).
- Lesson 6: "Your team must also compose how-to instructions for the assembly and use of your homemade heater. You may choose to use the space below and on the back of this page to draft your how-to instructions, and/or your teacher may provide other options for you to use" (Design Model Must-Haves Handout).

- Lesson 7: "Say, Listen carefully to the successes that other teams have experienced with their designs because we will come together in the Engineers Circle to share the most promising ideas. It may be useful for you to make notes in your science notebook about promising ideas so that you can reference them later in our whole-group discussion and when you are making decisions about the next revision of your team's design. Circulate and listen in as students are sharing their designs with partner teams. Push students to back up the performance of different design characteristics with evidence from their investigations and encourage students to listen to, compare, and critique the designs of partner teams" (Teacher Edition, page 190).
- Lesson 8: "Give directions for the Discussion Diamond protocol. Display slide C. Say, In a moment, we will share our ideas with the rest of our team. To make it easy to compare ideas and give each person a chance to speak, we will use the Discussion Diamond protocol. Pass out one copy of Discussion Diamond Graphic Organizer to each team. To begin, each team member will quickly jot the criteria/constraints they ranked as first and second most important in their corner of the handout" (Teacher Edition, page 201).
- Lesson 10: "Use the Design Testing Matrix to write an argument below that states whether incubator A will be sufficient to incubate sea turtle eggs effectively during relocation. Consider the criteria and constraints presented in the Design Testing Matrix and the advertised performance of incubator A in your argument" (Sea Turtle Assessment, page 3).

There are many examples of places in the Teacher Guide where mathematics and ELA standards that are used in the unit are identified for the teacher, as well as providing supports for students to engage in these standards and see connections. Some examples include:

- In the Teacher Background Information in the Teacher Edition (pages 15–16), necessary student prior knowledge for different CCSS in mathematics and ELA are called out, including what lessons they will use those skills.
- Lesson 1: "CCSS.ELA-LITERACY.SL.7.1: Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade 7 topics, texts, and issues, building on others' ideas and expressing their own clearly. CCSS.ELA-LITERACY.SL.7.1.C: Pose questions that elicit elaboration and respond to others' questions and comments with relevant observations and ideas that bring the discussion back on topic as needed.
During this lesson, students have several opportunities to talk—expressing their own ideas clearly and building on the ideas of others — with their classmates, from partner sharing to whole-group discussions. However, round 2 of the Talking Sticks activity used for sharing initial design models is a key moment to look for students to pose questions and comments to their peers and respond with relevant responses and observations." (Teacher Edition, page 50).
- Lesson 3: "CCSS.MATH.CONTENT.7.RP.A.1: Analyze proportional relationships and use them to solve real-world and mathematical problems. Students will have the opportunity to use proportional relationships in this lesson as they consider energy transfer in systems that are twice the amount and half the amount. Students will predict the temperature of a food system when energy is transferred from a chemical reaction of a set mass. Then students will reason and predict temperatures of the food system when 2X the mass of reactants are used in the chemical reaction. This early practice analyzing and predicting proportional relationships will help them in future lessons as they consider halving their system and predicting the results" (Teacher Edition, page 117).
- Lesson 4: "SUPPORTING STUDENTS IN ENGAGING IN USING MATHEMATICS AND COMPUTATIONAL THINKING - Students apply mathematical concepts from the CCSS for 6th

grade math to determine the optimal proportion of reactants by calculating the percentage of each substance. They should know to find a percentage they need to take a part (like 0.5) over the whole (5.5 + 0.5) and then find the equivalent proportion over 100 to get the percentage. While students should be able to calculate this, it may be a useful time to have some kind of anchor chart reminding them that a percentage is calculated as a part over a whole or showing a sample calculation of a percentage from a ratio. Additionally, showing strategies from their math class on finding equivalent ratios, like ratio tables or double number-line diagrams, may be helpful" (Teacher Edition, page 131).

- Lesson 7: "Say, These are all important to help us learn from one another as we share our designs with other teams. You will want to ask questions related to the team's designs and instructions. Listen carefully to learn more about their thinking and reasoning. You will respond in the same way. These are important communication skills for science and engineering as well as in all of your classes. Have any of you worked on these skills in your Language Arts classes?... Students may respond that they have because this skill is emphasized in CCSS.ELA-LITERACY.SL.7.1.A and CCSS.ELA-LITERACY.SL.7.1.C. See the end of this teacher guide for more details. Consider talking with the students' ELA teacher about how to support this standard" (Teacher Edition, page 189)
- Lesson 9: "CCSS.MATH.CONTENT.7.G.B.6 Solve real-world and mathematical problems involving area, volume and surface area of two- and three-dimensional objects composed of triangles, quadrilaterals, polygons, cubes, and right prisms. Students may want to redesign their homemade heaters to increase the surface area of the reactant system that is in contact with the food system. While mathematical calculation of surface area will not be necessary for these design improvements, it may be helpful if students understand the concept of surface area" (Teacher Edition, page 230).

Students are provided some reading opportunities in this unit, but student reading is limited in the variety of reading materials provided (articles that include charts, tables, graphs, and a lab procedure document). Examples of reading materials include:

- *Ingredient List for the MRE Heater* (Lesson 2)
- *Investigation Procedure for Proportion of Reactants and Analyzing Our Data Collection Methods* (Lesson 4)
- *Article: How hot does food need to get so that people don't get sick?* (Lesson 5)
- *Article: What temperatures cause scald burn injuries?* (Lesson 5)
- *Article: What temperature range makes food enjoyable to eat?* (Lesson 5)
- *Flameless Heater Instructions from other Teams* (Lesson 9)
- *Sea Turtle Population in Danger? Task* (Lesson 10)

Suggestions for Improvement

Consider providing additional opportunities for students to engage with a variety of reading materials such as scientific texts, news articles, journal articles, infographics, and websites or scientific organizations/entities to allow students to develop robust reading skills to better understand and explain scientific concepts.

OVERALL CATEGORY I SCORE: 3 (0, 1, 2, 3)	
Unit Scoring Guide – Category I	
Criteria A-F	
3	At least adequate evidence for all of the unit criteria in the category; extensive evidence for criteria A–C
2	At least some evidence for all unit criteria in Category I (A–F); adequate evidence for criteria A–C
1	Adequate evidence for some criteria in Category I, but inadequate/no evidence for at least one criterion A–C
0	Inadequate (or no) evidence to meet any criteria in Category I (A–F)

CATEGORY II

NGSS INSTRUCTIONAL SUPPORTS

II.A. RELEVANCE AND AUTHENTICITY

II.B. STUDENT IDEAS

II.C. BUILDING PROGRESSIONS

II.D. SCIENTIFIC ACCURACY

II.E. DIFFERENTIATED INSTRUCTION

II.F. TEACHER SUPPORT FOR UNIT COHERENCE

II.G. SCAFFOLDED DIFFERENTIATION OVER TIME

II.A. RELEVANCE AND AUTHENTICITY

Engages students in authentic and meaningful scenarios that reflect the practice of science and engineering as experienced in the real world.

i. Students experience phenomena or design problems as directly as possible (firsthand or through media representations).

ii. Includes suggestions for how to connect instruction to the students' home, neighborhood, community and/or culture as appropriate.

iii. Provides opportunities for students to connect their explanation of a phenomenon and/or their design solution to a problem to questions from their own experience.

Rating for Criterion II.A. Relevance and Authenticity	Extensive *(None, Inadequate, Adequate, Extensive)*

The reviewers found extensive evidence that the materials engage students in authentic and meaningful scenarios that reflect the real world because the phenomenon and problem used for the unit is engaging to students and reflects a real-world problem that affects people's lives. Therefore, it is clear to students that solving the problem is important to people. Students experience the phenomenon as directly as possible and are able to connect the problem and phenomenon to their own community through the stakeholder surveys they use when improving their designs.

Students experience phenomena or design problems as directly as possible.

- Lesson 1: "Show a few images of MREs being distributed. Display slide C. Say, Sometimes there are such big storms that whole cities don't have power. In this case, Superstorm Sandy knocked out power to New York City. In situations like these, helpers passed out something called Meals, Ready-to-Eat, or MREs" (Teacher Edition, page 27).
- Lesson 1: "Observe the MRE's flameless heater. Open the MRE package and remove the flameless heater first. Say, OK, so this is the part that actually does the heating up of the food, and I want us to get a good look at it. So, I have some extras of these to pass around. Be gentle with them and don't open them but take a look at one and record what you notice and wonder… Pass around the extra flameless heaters for students to observe up close, keeping the one from the package near you. After a minute, let the extra heaters continue circulating among the group and say, It says here we just need to add water, right? So let's try this! Heat the MRE's main entree using the flameless heater. … Remind students to record in their notebooks their noticings and wonderings about this heating process. ... Watch a video of a person eating an MRE. Display slide G. Say, Our flameless heater here needs a few more minutes to heat up. Since we can't eat what's in the MRE here in our class, I have a video of someone who tried one so we can see what he has to say about it" (Teacher Edition, page 29).

Throughout the unit, suggestions are provided for the teacher to connect instruction to the students' home, neighborhood, community, and culture. For example:

- Lesson 1: Student's home learning for Day 1 is to survey their friends and families about what they know about MREs. The next day students review the community survey results and record what they notice and wonder about the results (Teacher Edition, pages 35–36).
- Lesson 4: "Let's think a little bit more about all the stakeholders that might exist for our homemade flameless heater designs. Who will benefit from using these homemade heaters?... Gather and refine questions to ask stakeholders. Conduct a brief discussion to compile questions to create a Stakeholder Survey specific to your classes. Say, You all have some great ideas! Let's get these ideas out on the table and then we can create a survey that we can use with our stakeholders… Create Stakeholder Survey. Add the first class's questions to the 'Questions' page on the form. … Say, I have this survey template that I thought we could use to compile all the classes' survey ideas together. Let's take the items that we just talked about and add them to it. Each class will add to this throughout the day, and we can all collect stakeholder feedback with this single survey. This will provide us with a wide range of stakeholder input that can help inform our designs… Assign Stakeholder Survey as home learning. Show slide S. Share the survey link with your students and ask them to use it to survey potential stakeholders in their lives (friends, family, household members, neighbors, and so forth)" (Teacher Edition, pages 135–138).
- Lesson 5: Students look at the survey results from their families, neighbors, and community to figure out what these stakeholders say is most important to help them determine criteria and constraints for their problem and to design their prototype (Teacher Edition, page 143).
- Lesson 8: "Say, Oh, that's right—these designs aren't really for us - at least not for everyday use. We want to be able to help people who need to use these in an emergency. Let's go back to our Progress Trackers and look at who we listed as our stakeholders. Ask students to turn to the page in their student notebook where the Progress Tracker was updated to define our stakeholders. Invite students to share the identities of the stakeholders we defined. Our stakeholders are: People in our community that might need have to warm up food this way, people caught in snow storms or other natural events, people who may not have access to a stove, a person buying supplies and making the heaters, a person eating the food heated up by the heater, and The Red Cross, FEMA, or other organizations that might be buying supplies for people to have the kits ahead of time, Landfills, Recycling centers… Students share stakeholder impact charts and weigh impacts on stakeholders to decide which changes the team will make for the heater redesign. After students have filled in their stakeholder impact charts, show slide J and ask students to discuss the following questions with their teams to help them decide on the changes they will ultimately implement in their final design: How important to you are the interests of this stakeholder? If the effect on this stakeholder is negative, do you feel that it is directly offset by greater good elsewhere?" (Teacher Edition, pages 208–209).
- Lesson 9: "Remind students that they made great progress in the unit by figuring out how to help people create a flameless heater through understanding What We Do as Engineers. Project slide V. Have students survey friends and family about their homemade flameless heater instructions using … You may want to direct your students to take a picture of their group's instructions so that they can use them when they survey people. Say, Let's check with others who aren't in our class to see if they understand our instructions, and think about how we might apply what we've figured out to another context. Before next time, survey 2 or more people, one can be your age, but the other should be an adult. You'll have to describe your heater and show them your instructions, so make sure you have what you need before you go!" (Teacher Edition, page 230).

Students have multiple opportunities to connect their explanation of the phenomenon and their design solution to their own experience.

- Lesson 1: “Say, I have a question to get us thinking about a new phenomenon we’re going to explore. Think about all the ways in which people can heat up food inside and outside of their homes. Turn to an elbow partner and start listing ways you know of that we can heat our food.” (Teacher Edition, page 27).
- Lesson 1: “Use the next clean page in your science notebook to list any and all situations--related to the ones we’ve already seen or other situations--in which you think it would be helpful to have a homemade flameless heater. Give students about 2 minutes to write their ideas. Share related situations where MREs would be useful” (Teacher Edition, page 36).
- Lesson 1: “Say, these flameless heaters and MREs are pretty useful, but they’re not perfect. What problems or issues do you see with using MREs with flameless heaters to get hot food to people when they don’t have their typical cooking methods available? Take a minute to jot down your ideas on the next clean page of your notebook… Have students gather in a Scientists Circle. Skim through the papers as you collect them, then read aloud and list on chart paper the most commonly written or checked problems. The problems you’ll want to call attention to (because they will be the most helpful in the upcoming steps) are the following: Cost: MREs are expensive! Availability: It can be difficult to get them or difficult to get them to people when needed. Ease of use: The directions are confusing. Lack of choice: Choice is limited to foods that come in the package” (Teacher Edition, pages 37–38).
- Lesson 1: “Suggested prompts - First of all, who can remind us of the problems we wanted our flameless heater to solve? Why did we want to design a different homemade one? Sample student responses - Prepackaged MREs are expensive! It can be hard to get MREs to people when they’re needed. MREs are sometimes confusing to use. There are limited food choices with prepackaged MREs” (Teacher Edition, page 45).
- Lesson 3: “Say, One combination of substances we will test is baking soda and vinegar. How many of you have mixed these two substances?... plant. We are going to combine root killer with aluminum foil and saltwater. How many of you have used aluminum foil before? How about saltwater?...” (Teacher Edition, page 86). In this lesson, students are using household chemicals to see what can be used to produce heat. The teacher connects students’ experiences with these household chemicals to the reactions they are about to test.
- Lesson 3: “Say, For a reaction that heats up, if we used more substances, would we get more heat, less heat, or the same amount of heat? What makes you think this? What related phenomena from your own experiences help you think this? Give students a minute to write their predictions in their notebooks” (Teacher Edition, page 88).
- Lesson 6: “Say, We have been working hard creating designs to help us build a working flameless heater. If we can’t communicate to others how to build our flameless heater, then our design would be ineffective. In Lesson 4 we started thinking and discussing what is needed for good instructions. Think about some different experiences where you had to follow instructions, maybe to put together a toy or cook something from a recipe or like the instructions we used in one of our earlier labs. Was anything difficult about following those instructions? Was there anything about them that made it easier to follow them or that you wished for that would have helped you? Turn and talk with a neighbor about your experiences following instructions” (Teacher Edition, page 175). Students’ prior experiences are used to help them see the importance of clear instructions for their design solution.

The materials provide support to teachers for anticipating issues that may arise when students communicate about their own lives. For example:

- Lesson 1: "If you know that you have students or their family members who were affected by natural hazards, such as Superstorm Sandy in New York or Hurricane Maria in Puerto Rico, check in with them before you share the photos in this lesson. If it will make them uncomfortable to be in the whole-group setting while the class views these photos, you may want to offer an alternate setting for those students to consider how MREs have been used in disaster response or modify for your class how you frame the use of MREs (such as selecting different images or talking about rather than showing images)" (Teacher Edition, page 27).

Suggestions for Improvement
None

II.B. STUDENT IDEAS

Provides opportunities for students to express, clarify, justify, interpret, and represent their ideas and respond to peer and teacher feedback orally and/or in written form as appropriate.

Rating for Criterion II.B. Student Ideas	Adequate *(None, Inadequate, Adequate, Extensive)*

The reviewers found adequate evidence that the materials provide students with opportunities to both share their ideas and thinking and respond to feedback on their ideas because students show how their thinking about their design solutions change over time as they incorporate what they learn about heat and chemical reactions, stakeholders' input, and their design tests. Throughout many lessons, students express, clarify, justify, interpret, and represent their ideas. Opportunities for students to reflect on feedback and show how their reflective thinking has changed over time are not present in the unit.

Teacher guidance to elicit student ideas are provided in many lessons. Some examples include:

- Lesson 1: "Share noticings and wonderings about the flameless heater. Display slide H. Invite students to share what they noticed and wondered about the flameless heater while you record their ideas on chart paper. This sharing should be focused first on what we experienced in the classroom; if students have other experiences to share, ask them to hold onto those ideas until after the class has finished creating the list from the flameless heater observations" (Teacher Edition, page 29).
- Lesson 1: "'Pass the Paper' to collect problem ideas. Display slide BB. Distribute a sheet of loose-leaf paper to each of 6-8 random students in the class. Explain the directions for this activity as follows: When you get a piece of paper, write one of your problems with getting hot food to people when they don't have their typical heating methods available. Also, if one of your ideas or a very similar one is already listed on a paper you get, put a check mark near it. We want to keep an informal tally of how many people thought of similar problems. If you think an idea that someone else has written is important, put a star near it, also. After you've

written an idea and checked any others as needed, pass the paper along to someone else" (Teacher Edition, page 37).

- Lesson 1: "Display slide MM. Distribute Initial Design Reflection. Direct students to answer these questions on the Initial Design Reflection handout before class meets again. What went well when creating or sharing your initial design? What was difficult about creating or sharing your initial design?" (Teacher Edition, page 44).
- Lesson 3: "2. Which process do you think is the best candidate for trying in our homemade flameless heater? Why do you think that? 3. Think back to what we learned in the Cup Design Unit. What happens to particles when the temperature increases? You can use words and/or pictures to explain your thinking" (Class Data Handout).
- Lesson 4: The class gathers in an Engineers' Circle and the teacher is instructed to "lead a Building Understandings Discussion to draw conclusions about the optimal proportion of reactants that results in the largest temperature change and what this means for our design solutions" (Teacher Edition, page 130). The teacher asks, "What claim can we make about which proportion of reactants worked the best? What is your evidence?" (Teacher Edition, page 131)
- Lesson 8: "Say, Then one-by-one each person will have 1 minute to explain their ranking using specific data from past investigations as evidence to support their ideas. Similar to the Talking Sticks protocol, no one gets to respond during round 1—each person is listening carefully to the speaker. After everyone has shared their justifications, begin round 2. In round 2, the purpose is to come to a consensus about which 2-3 things your team wants to modify for the final homemade heater design. The whole team has a chance to talk freely with each other, to ask questions to specific team members, and to add any ideas you may have thought of as other team members presented their ideas. Keep your Design Testing Matrix out as well, and use the information there to support your ideas during the discussion. The goal is for your team to be in agreement about which 2-3 elements to change by the end of this discussion" (Teacher Edition, page 201).
- Lesson 8: "When teams have decided which of the changes they want to implement, conclude the decision-making process by asking students to individually report the constraints, criteria, and stakeholder impacts that were considered as they justify their decisions in their science notebooks. Display slide L and ask students to turn to the next free page in their science notebooks to complete the following prompt: Describe the changes you will make to your design, and justify those changes — include an explanation of how both positive and negative impacts on stakeholders were considered in your decision" (Teacher Edition, page 212).
- Lesson 10: "3d. Beyond temperature, which additional characteristics from each design would you use in your optimal design? To do this, go through each criterion and constraint and state your reasons (including discussion of how energy is transferred) for which design (incubator A or B) you would choose for that characteristic" (Sea Turtle Assessment, page 7).

Supports are provided to help both the teacher and peers provide feedback orally and in written form.

- Lesson 6: "If a team's design does not include characteristics related to the criteria and constraints (such as cost or type of materials used), remind the team to go back and add those. If a team is struggling to calculate the amount of reactants they want to use, suggest that they base their plans on prior test results, such as those from Lesson 4 (that 6 grams of total reactants in the most efficient proportion was able to heat up significantly) and consider if they might double or triple that amount (knowing that they will need more energy to heat more food). If a team's design does not include the energy transfer at the particle level, it may be helpful to refer to the initial consensus model you made as a class in Lesson 1 that shows how the MRE heater's particles were moving and ask the team to consider how that might be similar to their design. If these students experienced OpenSciEd Unit 6.2: How can containers keep stuff from warming up or cooling down? (Cup Design Unit), referring to the models they drew of the energy transfer happening with their cups may also be helpful" (Teacher Edition, page 172).

- Lesson 7: "Display slide C and use it to explain the process for sharing designs among teams. Explain the following: 2 min: Have each team exchange the instructions for building their design to scale (from Lesson 6). Each team should give feedback to their partner team's instructions by writing feedback on sticky notes and adding to the team's How-to Instructions written at the bottom of How-to Instructions Must-Haves. Ask clarifying questions or give feedback that will help them improve their instructions. 6 min: Each team will have 3 minutes to verbally share their design with their partner team . Partner teams should record information about how the presenting team's design performed. 4 min: Then partner teams will have 4 minutes to individually give written feedback using the guiding questions in their Peer Feedback on Designs. … Partner teams give each other the completed feedback tables from Peer Feedback on Designs and return the instructions with sticky note feedback added before parting ways. Teams will complete two rounds of sharing using this process." (Teacher Edition, pages 189–190)
- Lesson 9: "Distribute copies of How-to Instructions Must-Haves and remind teams to review and use the following as they revise their instructions: the partner team sticky note feedback they received on How-to Instructions Must-Haves in Lesson 7, their Consequences Chart from Lesson 8, their Stakeholder Impact Chart from Lesson 8, and their Design Testing Matrix. Previously students have used the Lesson 8 materials to revise their designs, but here they should use those materials in addition to the Lesson 7 partner team sticky note feedback to revise their instructions" (Teacher Edition, page 223).

Suggestions for Improvement

Consider providing additional opportunities for students to show how their individual thinking has changed throughout the course of the unit, especially after receiving feedback. Additional feedback cycles like the one in Lessons 7 and 9 would strengthen the unit to extensive, especially if students are provided with time and support to reflect and respond to the feedback they are given from peers and teachers.

II.C. BUILDING PROGRESSIONS

Identifies and builds on students' prior learning in all three dimensions, including providing the following support to teachers:

i. Explicitly identifying prior student learning expected for all three dimensions
ii. Clearly explaining how the prior learning will be built upon.

Rating for Criterion II.C. Building Progressions	Adequate *(None, Inadequate, Adequate, Extensive)*

The reviewers found adequate evidence that the materials identify and build on students' prior learning in all three dimensions because the materials clearly state the expected prior learning in individual elements of all three dimensions. Learning progressions within the unit are called out in sidebars that provide support for developing some of the targeted elements of the SEPs and CCCs with explanations for how students' learning fits with previous and future lessons. Learning in all three dimensions progresses and builds logically throughout the unit. Explanations for how prior learning in all targeted elements will be built upon throughout the unit is not present. Additionally, there aren't enough supports for addressing student alternate preconceptions.

The unit materials clearly identify prior student learning in all three dimensions and explain how students' prior learning will be built upon. For example:

- In the section "What should my students know from earlier grades or units?" (Teacher Edition, page 13), the DCI elements from prior grade bands and units in the OpenSciEd instructional sequence are addressed. There is also an explanation as to how the DCI elements will be built upon in this unit (Teacher Edition, page 14).
- In the "What should my students know from earlier grades or units?" section of the Teacher Edition (page 13), CCC and SEP elements from the Grade 3–5 are listed. There are no explanations on how the CCC and SEP elements will be built upon throughout the unit in this section.
- Sidebars in the Teacher Edition call out places where students are building understanding of the elements of the SEPs and CCCs. Many of these sidebars describe how prior learning will be built upon. For example:
    - Lesson 2: "SUPPORTING STUDENTS IN DEVELOPING AND USING SYSTEMS AND SYSTEM MODELS - Carefully defining the system boundaries and defining the parts of the MRE system will motivate students to think about what (in the MRE system) the thermometer is measuring. With system boundaries clearly defined, students see that energy is transferred from the system of rearranging atoms to the surroundings in the case of an exothermic reaction and from the surroundings to the system of rearranging atoms in the case of an endothermic reaction; linking the idea of the thermometer measuring the surroundings will help students make sense of these ideas when they surface in Lesson 3" (Teacher Edition, page 58).
    - Lesson 2: "SUPPORTING STUDENTS IN DEVELOPING AND USING ENERGY AND MATTER - Reviewing how thermometers work is a key piece to scaffold the crosscutting concept of energy transfer in chemical reactions. Later in this lesson, students will further develop these concepts when modeling the energy transfer and track the energy as it flows between parts of the MRE system" (Teacher Edition, page 59).
    - Lesson 3: "SUPPORTING STUDENTS IN ENGAGING IN PLANNING AND CARRYING OUT INVESTIGATIONS - The data produced in carrying out this investigation serves as evidence for students to choose the best reaction to use in their homemade flameless heaters. As students are conducting this investigation, remind them of this purpose and emphasize this important practice of science and engineering to use in our engineering design process" (Teacher Edition, page 89).

  - Lesson 3: "SUPPORTING STUDENTS IN DEVELOPING AND USING ENERGY AND MATTER - This discussion of energy transfer from the chemical reaction is tricky--especially when you are limited in middle school to the depth to which you can explain. If students wonder where the energy comes from, the answer will get into high school-level content. One way to address their curiosity if it comes up is to ask them what they do know about the reaction. They know particles break apart and rearrange in the reaction and energy is transferred to the surroundings in an exothermic reaction. Students can reason that the energy must come from the reaction" (Teacher Edition, page 103).
  - Lesson 5: "SUPPORTING STUDENTS IN ENGAGING IN OBTAINING, EVALUATING, AND COMMUNICATING INFORMATION - When students are working on their own, check in with individual students and notice whether they are identifying and noting the central ideas to answer one or more of the focal questions. If students are not adding notations or if they are using a lot of time to annotate parts of the reading not directly related to the focal questions, direct them to the slide and encourage them to focus on using the tags to be specific about the information they want to report to their small group" (Teacher Edition, page 144).
  - Lesson 9: "SUPPORTING STUDENTS IN DEVELOPING AND USING ENERGY AND MATTER - Design Must-Haves provides opportunities for students to model energy flow at the system level and the particle level. Students used energy transfer models in Lessons 3 and 6 to explain energy transfer between systems and Lesson 10 will require students to use an energy transfer model in a new context. Prompt students to think about how the energy transfer and particle models for their revised designs differ from those for their earlier designs. The first energy transfer model they would draw would be the amounts of reactants used in Lesson 6 and the second would be the change they expect to achieve in this lesson" (Teacher Edition, page 222).
- In the "Where are We Going" Section of each lesson in the Teacher Edition, student learning for that lesson is described and some lessons also describe how students' prior learning in the SEPs and CCCs will be built upon. For example:
  - Lesson 3: "They will track the energy transfer into or out of the various systems involved (the substances themselves as well as the cup holding them, the air, the thermometer, and so forth) to help figure out that the energy from a chemical reaction could be transferred to heat up the food in our homemade flameless heater. After choosing the best reaction to move forward to heat food, students build particle models using what they figured out from OpenSciEd Unit 6.2: How can containers keep stuff from warming up or cooling down? (Cup Design Unit) and OpenSciEd Unit 7.1: How can we make something new that was not there before? (Bath Bombs Unit) to explain what is going on with the chemical reaction and energy transfer… Students develop and use Energy Transfer Models to predict temperature changes when increasing the amount of food and/or increasing the amounts of reactants" (Teacher Edition, page 85).
  - Lesson 7: "In the previous lesson, students tested their flameless heater designs and collected data to inform their next redesign. The small- and whole-group discussions in this lesson allow students to identify the most promising design features of a flameless heater and begin to think about what changes they want to make to their team's design and what consequences might occur as a result of those changes. This lesson gives students opportunities for authentic scientific communication, including

supporting claims about performance with evidence from investigations, providing and receiving critiques, and asking questions for clarification" (Teacher Edition, page 188).
  - Lesson 10: "Students will have an opportunity to demonstrate understanding on a summative assessment transfer task about sea turtle incubators. Over the course of the unit students have been building understandings of the four key DCIs that this assessment targets: (1) PS1.B Some chemical reactions release energy; others store energy; (2) ETS1.B There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem; (3) ETS1.B Sometimes parts of different solutions can be combined to create a solution that is better than any of its predecessors; and (4) ETS1.C Although one design may not perform the best across all tests, identifying the characteristics of the design that performed the best in each test can provide useful information for the redesign process—that is, some of the characteristics may be incorporated into the new design" (Teacher Edition, page 234).

The unit provides little support for teachers to address and clarify student alternate conceptions in the CCCs. For example:

- The "What are some common ideas that students might have?" section of the Teacher Edition (page 14) provides discussion on general preconceptions that students may have in the areas of **Systems and System Models** and **Energy Transfer: "**This unit will focus a great deal on energy transfer between systems. However, at the start of this unit, students may or may not identify the heater and food as two distinct systems, and they may not yet name energy transfer as the cause for the food heating up. Working with students to use the CCC lens of Systems and System Models will help them accurately identify energy transfers to and from chemical reactions..." However, additional support throughout the unit on student preconceptions and alternate conceptions in all three dimensions is not found.

Suggestions for Improvement

- Provide a summary document or pages in the Teacher's Edition that highlights how each element is built upon throughout the unit. For example, for the CCC element, *Models can be used to represent systems and their interactions — such as inputs, processes, and outputs — and energy and matter flows within systems*, show which lessons students are using or developing the element and how it is being built upon and progressed through these lessons.
- Consider adding additional guidance for teachers to clarify any potential alternative conceptions students have in targeted elements of all three dimensions.

II.D. SCIENTIFIC ACCURACY

Uses scientifically accurate and grade-appropriate scientific information, phenomena, and representations to support students' three-dimensional learning.

Rating for Criterion II.D. Scientific Accuracy	Extensive *(None, Inadequate, Adequate, Extensive)*

The reviewers found extensive evidence that the materials use scientifically accurate and grade-appropriate scientific information because all science ideas and representations included in the materials are accurate and based on scientifically reliable sources.

Related evidence includes:

- The unit provides an extensive Teacher Background section in the Teacher Edition with information about lab safety and how the DCIs are used in the context of this unit (Teacher Edition, pages 10–12).
- “Additional Guidance” sections throughout the Teacher Edition provide background information for the teacher that is scientifically accurate.
- Teacher discourse concerning chemical reactions and thermal energy contain scientifically accurate information.
- In Lesson 5, Section 2, students read articles about the effects of different temperatures on disease-causing microorganisms, human taste buds, and the human mouth (Teacher Edition, page 105). These articles are written at a grade-appropriate level and cite reliable sources for the information included (e.g., www.cdc.org, www.foodsafety.gov, www.npr.org, www.Harvard.edu, etc.).

Suggestions for Improvement

None

II.E. DIFFERENTIATED INSTRUCTION

Provides guidance for teachers to support differentiated instruction by including:

i. Supportive ways to access instruction, including appropriate linguistic, visual, and kinesthetic engagement opportunities that are essential for effective science and engineering learning and particularly beneficial for multilingual learners and students with disabilities.

ii. Extra support (e.g., phenomena, representations, tasks) for students who are struggling to meet the targeted expectations.

iii. Extensions for students with high interest or who have already met the performance expectations to develop deeper understanding of the practices, disciplinary core ideas, and crosscutting concepts.

Rating for Criterion II.E. Differentiated Instruction	Adequate *(None, Inadequate, Adequate, Extensive)*

The reviewers found adequate evidence that the materials provide guidance for teachers to support differentiated instruction because multiple specific strategies are provided for emerging multilingual learners, struggling learners, and learners who read well below grade level; however, support is limited for learners with disabilities and students who have already met the performance expectation. General differentiation guidance is also provided in the OpenSciEd Teacher Handbook, but it is not specific to this unit.

Appropriate reading, writing, listening, and/or speaking alternatives are suggested for students who are emerging multilingual learners, learners with disabilities, or read well below the grade level. For example:

- The Guidance for Developing Your Word Wall section states, “It is especially important for emergent multilingual students to have a reference for this important vocabulary, which includes an accessible definition and visual support. Sometimes creating Word Wall cards in the moment is a challenge” (Teacher Edition, page 19).
- Lesson 2: “Students may benefit from sentence starters to help them express what they see. Consider providing some sentence or question starters such as these…” (Teacher Edition, page 69).
- Lesson 3: “Supporting Emerging Multilinguals: You might also intentionally group emerging multilingual students with certain peers who know the same languages or with peers whose English language development is slightly more advanced” (Teacher Edition, page 87).
- Lesson 3: “Supporting Emerging Multilinguals: When new scientific words like exothermic and endothermic are introduced, it can be helpful for emerging multilingual students to see representation of the new term in multiple ways. For example, students can (1) write the term, (2) draw a representation of the term, (3) use their own words to write an explanation for what the term means, and (4) use the new term in a sentence” (Teacher Edition, page 93).
- Lesson 3: “Supporting Universal Design for Learning: Use representations like color coding and/or letter or number coding to foreground parts of the model. Create a key to track what colors, symbols, or letter or number codes represent different parts of the system. The example model uses different colors to represent different types of particles. It is equally acceptable to use different shapes, drawn textures, or other ways to distinguish particles. What is important is that different particles are represented in different ways. While color coding is a useful way to quickly reference the parts of the model, letter or number coding helps ensure accessibility for any student who may be color blind. If color coding is used, consider a color palette that uses orange, blue, black, or dark brown” (Teacher Edition, page 98).
- Lesson 4: “Universal Design for Learning: Students can use a calculator to help determine the percentages. Allowing alternatives for use of tools, such as a calculator, can remove barriers for students in expressing their understanding by keeping the focus on the learning goal” (Teacher Edition, page 130).
- Lesson 5: “Asking students to annotate the readings with symbols or tags can help students manage information so that they can express their understanding. Students may need additional support in obtaining information from the provided readings. Consider including any of the following options to support students who read below grade-level: Have students work with a partner as they read and annotate their assigned reading. Strategically assign particular readings based on student reading level and interest. Alternatively, assign only the first page of handout or student reference Reading: What temperature range makes food enjoyable to eat?, which includes only the taste test results in table form, to students who may benefit from focusing on just the visual display of data. Provide a checklist with the 3 focal questions and their tags for students to use as they read. See slide B. Allow for a competent aide, partner, or “intervener” to read the text aloud” (Teacher Edition, pages 143–144).

The Assessment Opportunity boxes in the Teacher Edition provides guidance for teachers to provide support for students who are struggling to meet the targeted performance expectations for each key assessment activity. Some examples include:

- Lesson 1: “What to do: If students are struggling to generate questions connected to their previous observations, direct them to their Notice and Wonder chart and related situations list. If students are struggling to seek information that could inform their design, point them to specific places in their initial design and ask, What would you need to know more about to figure this out?” (Teacher Edition, page 47).
- Lesson 2: “What to do: If students are struggling to generate questions connected to their previous observations, direct them to their Notice and Wonder chart and related situations list. If students are struggling to seek information that could inform their design, point them to specific places in their initial design and ask, What would you need to know more about to figure this out?” (Teacher Edition, page 78).
- Lesson 3: “If students are struggling to determine the maximum temperature change for the reaction that causes a temperature decrease and has a negative value (baking soda in vinegar), have them create a number line to see that temperature changes can occur in either direction. Ask questions about the direction of energy flow between each reaction and the thermometer to start students thinking about energy. This will help them with the questions at the end of the handout, Class Data for Chemical Reactions Lab” (Teacher Edition, page 90).
- Lesson 3: “If students need further support in understanding the chemical equation and how it helps show that the atoms we start with are the same as the atoms at the end (they are just rearranged), you can connect back to the key ideas from Bath Bombs Unit and continue the discussion. Start with reminding them of the Key Model Ideas poster from Bath Bombs Unit. Bring out the Key Model Ideas poster if you still have it in your classroom. If students are confused, then break down every atom in this chemical reaction, $3CuSO + 2Al \rightarrow 3Cu + Al (SO)$. In Bath Bombs Unit students did not see a chemical equation that used parentheses, so that may be a point of confusion that arises and needs to be clarified. Below are some suggested prompts for that extended conversation” (Teacher Edition, page 102).
- Lesson 4: “ If students are struggling to connect what they see with the remaining solids and liquids after the reaction to their temperature change results, draw attention to the reaction equation and pose questions, such as these: What did the reactants look like before? How does that compare to what is left afterward? How does the pattern in appearance of the products (what is left afterward) correlate with the temperature change pattern?” (Teacher Edition, page 133).
- Lesson 8: “Working memory is very limited for any learner and even more severely limited for many learners with learning and cognitive disabilities. Providing a graphic organizer, reminding students to refer to other documents for evidence, and embedding prompts for all students to use helps all students better visualize chunks of information. This will allow the pieces of information to be accessed easily, which is especially important to support expression during complex verbal practices like argumentation, explanation, and communication” (Teacher Edition, page 201).
- Lesson 8: “ALTERNATE ACTIVITY - If you think your students would benefit from extra practice considering cascading consequences or to understand the purpose of this chart, an optional 10-minute extension is provided in Unknown material with identifier: cb.l8.tref and optional slide F1 is provided to support the activity” (Teacher Edition, page 203).

Minimal guidance is provided for students who have already met the performance expectation. The evidence found are listed as "alternative activities" and not identified as activities for students who have already met the performance expectations and do not necessarily support these students in a deeper understanding of the three dimensions. For example:

- Lesson 1: "If time allows, you may want to provide more context about the development of MREs. The video available at www.teachersopensciedfieldtest.org/heater explains how the US military's goal with MREs is to not only provide proper nutrition to the troops but to give them a sense of comfort and home with this food, as well" (Teacher Edition, page 27).
- Lesson 3: "As an extension activity, students can collect some of the gas and conduct a flammability test as in OpenSciEd Unit 7.1: How can we make something new that was not there before? (Bath Bombs Unit)" (Teacher Edition, page 89).
- Lesson 6: "Extension: Your students may mention their experiences watching how-to videos as an example of helpful instructions. If time and resources are available, you may choose to give students the option of creating a video for their homemade heater assembly-and-use instructions. If you have resources but not time for videos here in Lesson 6, you may choose to offer video as an option for the redesign during Lesson 9 (as a way to improve or optimize the design for this criterion)" (Teacher Edition, page 175).
- Lesson 9: "After teams test their own revised design, you may want to give them more time to undergo another round of redesign and testing. Students will probably need another class period to make and test meaningful design modifications. This decision is up to your discretion and should be based on available time and student interest" (Teacher Edition, page 226).

Suggestions for Improvement

- Consider providing explicit suggestions to address the needs of learners with disabilities.
- Consider providing extension activities or suggestions that include supporting the development of the three dimensions for students who have already met the performance expectations.

II.F. TEACHER SUPPORT FOR UNIT COHERENCE

Supports teachers in facilitating coherent student learning experiences over time by:

i. Providing strategies for linking student engagement across lessons (e.g. cultivating new student questions at the end of a lesson in a way that leads to future lessons, helping students connect related problems and phenomena across lessons, etc.).

ii. Providing strategies for ensuring student sense-making and/or problem-solving is linked to learning in all three dimensions.

Rating for Criterion II.F. Teacher Support for Unit Coherence	Extensive *(None, Inadequate, Adequate, Extensive)*

The reviewers found extensive evidence that the materials support teachers in facilitating coherent student learning experiences over time because several supports and strategies are provided for teachers to create a coherent path of learning, connecting across lessons, and allow students to see how their progress is linked to designing their solutions.

- At the beginning of each lesson in the Teacher Edition there is a "Where We Are Going and NOT Going" statement that explains the summary of what the key points of the lesson are for teachers as well as areas they shouldn't go to in that specific lesson.
- Each lesson begins with a "Navigation" part linking each lesson to the previous lesson, in which students and the teacher summarize their learning so far and look at what needs to be figured out next.
- The Design Question Bank is a record of initial student questions about the phenomenon/problem and is developed in Lesson 1. Students refer back to this document during lessons 2, 4, 6, and 9 to see which questions they can answer and which they still need more information about.
- The Progress Tracker is revisited during almost every lesson. This Progress Tracker has a record of student learning, wonderings, and what the students have learned about the engineering process.
- Teachers are given support to create the "What We Do as Engineers" board in Lesson 1, which contains a class consensus summary of what they have learned about the engineering design process. This board is referred back to and amended in Lessons 2,3, and 4 with what they are doing to solve the problem. Then in Lesson 5 students organize the board around the titles, "Define", "Optimize," and "Develop Solutions." Arrows are also added to the graphic organizer.
- The "Ideas for Investigations" document is developed in Lesson 1. This has a student-generated list of what possible investigations they might need to do to understand the phenomenon of the flameless heater and solve their problem of making an inexpensive, homemade, flameless heater. This document is referred back to in lessons 2, 3, and 6.
- Teacher prompts are provided at the beginning and end of each lesson as well as throughout lessons to support teachers in connecting student learning throughout the lessons. A few examples are provided here:
    - Lesson 3: "Recap where we left off in Lesson 2. Have the What We Do as Engineers board, the class-level Criteria and Constraints chart, and the Ideas for Investigations class chart from Lesson 1 posted and visible to the class. Display slide A. Use the following prompt-response box to navigate to the investigation of different chemical reactions. If students are struggling to answer the prompts, have them refer to their Progress Tracker. What did we figure out last time about using the materials in the MRE flameless heater or the hand warmer in our own designs? For our homemade heater, what do we need the chemical reaction to do? What are our criteria for it?" (Teacher Edition, page 86).
    - Lesson 3: "Think back to what we learned in Cup Design Unit. What happens to particles when the temperature increases? You can use words and/or pictures to explain your thinking. 4. What happened to the temperature when we added more reactants?" (Teacher Edition, page 92).
    - Lesson 4: "Display slide A and make sure that the DQB is visible. Say, Last time, we figured out that mixing copper sulfate and aluminum foil together transferred a lot of energy out of the reaction system. It seems like we've got a good start for creating a flameless heater, including a good reaction to use. But I'm wondering, how exactly can we help people use that reaction in order to build their own flameless heater? Turn and talk with an elbow partner and discuss what we should do as our next steps if we

want to help people make homemade heaters to warm up their food. What else do we need to figure out about the reaction system?" (Teacher Edition, page 125).

- Lesson 5: "Organize the criteria we need to consider for our design solutions. Draw students' attention to the initial Criteria and Constraints chart that was created in Lesson 1. Say, Now that we have a more-specific idea about the range of temperature to which food should be heated, we should update our list of criteria and constraints. But now, after looking at this chart, it seems like we have a lot of different ideas we are going to need to consider. It seems like it would be easy to get too focused on one of these criteria or constraints while accidentally ignoring others. Let's reorganize this list so that we can keep track of all our criteria and constraints" (Teacher Edition, page 146).
- Lesson 5: "OK, so far, we've worked in "Define," "Develop" and "Optimize," and today we ended back in "Define" as we worked on refining our criteria and constraints and narrowed down what our optimal design should do. Using this engineering process that we've developed, where should we go next? How do we get started on this? Should we just throw some random amounts of chemicals together to heat up random amounts of food? Would that be a responsible use of our resources? Say, Great, that's where we'll go next time!" (Teacher Edition, page 155).
- Lesson 6: "Revisit our DQB and Ideas for Investigations chart to mark off what we have accomplished. Display slide B and give every student one sticky note. Direct students to write a check mark on the sticky note and then come up to the Design Questions Board and/or Ideas for Investigations chart and attach their sticky note near a question or investigation idea that the class has already completed. This is meant to be a quick trip to the charts and sit back down—no deliberation needed. If someone else has already put a sticky note where they had planned to, the student can add their sticky note on top of that one or find another question or investigation that has been completed" (Teacher Edition, page 166).
- Lesson 6: "To help us think about how we can improve our designs we need to consider how different components or systems of our design are interacting with each other in order to transfer energy to heat up our food to 40-47 degrees Celsius. Let's return to our Energy Transfer Model to help us reflect on our designs so that next class we can begin to discuss ways of improving them" (Teacher Edition, page 183).

Suggestions for Improvement

Consider providing explicit guidance for teachers to regularly review with students how their learning in all three dimensions is helping them to make sense of the flameless heater phenomenon and improve their designs. While this is done in some lessons, more frequent and clear connections to prior learning in all three dimensions is helpful in the instructions.

II.G. SCAFFOLDED DIFFERENTIATION OVER TIME

Provides supports to help students engage in the practices as needed and gradually adjusts supports over time so that students are increasingly responsible for making sense of phenomena and/or designing solutions to problems.

How Can We Use Chemical Reactions to Design a Solution to a Problem?

EQuIP RUBRIC FOR SCIENCE EVALUATION

Rating for Criterion II.G. Scaffolded Differentiation Over Time	Adequate *(None, Inadequate, Adequate, Extensive)*

The reviewers found adequate evidence that the materials support teachers in helping students engage in the practices as needed and gradually adjust supports over time because teacher-provided scaffolding is reduced over time for students as they show higher independence in using one of the targeted SEP elements. Reduced scaffolding over time is not provided for all targeted SEP elements in the unit.

Teacher scaffolding is provided at the beginning of the unit and reduced over the learning sequence of the SEP element, *Develop a model to generate data to test ideas about designed systems, including those representing inputs and outputs*. Related evidence includes:

- Lesson 1: "Gather in a Scientists Circle and co-construct an initial consensus model. Display slide M. Direct students to form a Scientists Circle. Discuss and construct an initial consensus model representing areas of agreement and areas of disagreement in the model. It is unlikely that you will have complete consensus about what is happening in the flameless heater. See the example consensus model shown here" (Teacher Edition, page 33). Here students are working as a whole class to develop a consensus model of how the flameless heater works.
- Lesson 2: "As you review these ideas as a class, facilitate the construction of a Thermometer Model to explain energy transfer through particle collisions. Start with a clean sheet of chart paper and have a few different colors of chart markers ready to draw components of the model as students surface ideas. This model will be an important artifact to look back to as the class begins to model the energy transfer in the MRE system later in this lesson" (Teacher Edition, page 58). In this lesson, the teacher reviews a model of energy transfer used in a previous unit to help prepare students for making their own models of energy inputs and outputs.
- Lesson 3: "Conduct a class discussion as the class builds a particle model of the reaction. Emphasize that we are just zooming in to the particles in the chemical reaction. Use the sample dialog below to guide the discussion as you build a particle model of the reaction so we can use it to figure out how energy interacts with our systems. Ask students to draw the model in their notebook as you draw it on the board" (Teacher Edition, page 99). Here the class model is becoming more sophisticated, but it is still done as a class discussion activity.
- Lesson 3: "Complete the model and share with a partner. Display slide Q. Ask students to complete the model using the same conventions. Tell them to write a short statement of what happens to the particles when they react and put it in the middle column. Then ask them to share with their elbow partner and make revisions if they learn something from their partner. Have students share ideas as you complete the class model on the board with students. Have students check their ideas. Complete the middle section by asking students to explain what happened to the particles from the first column to the last" (Teacher Edition, page 100). Here, students are asked to complete the model on their own and then check with a partner before having a class discussion over the finished models.
- Lesson 3: "Assign student pairs to create their own Energy Transfer Models. Have student pairs copy in the first row of Energy Transfer Models the simple box model you just made on the board for the 1X reaction/1X food system. They should work with their partner to create a new Energy Transfer Model in the second row that would model the energy transfer from 2X the reactants to the same amount of food. They should be ready to share their results with the class in 5 minutes. Encourage them to use the model the class made together for the 1X

reaction/1X food system as an example" (Teacher Edition, page 108). After seeing a new sample model from the teacher, students work in pairs to develop their own Energy Transfer Model for a new situation.

- Lesson 10: "Draw a model to explain "How does the heat pack keep the turtle eggs warm?" Update the Energy Transfer Model to show how the energy is transferred between the reaction occurring in the heat pack and the incubator system containing the turtle eggs. Include a representation of what is happening to the substances that are undergoing the chemical reaction. Use the table below the Energy Transfer Model to explain what is happening at the scale we cannot see. Use the space in the table to draw a representation of what is happening to the substances that are undergoing the chemical reaction" (Sea Turtle Assessment, page 4). In Lesson 10 students must individually show their progress in developing a model showing inputs and outputs of energy without teacher or group supports.

Suggestions for Improvement

Consider providing additional support for teachers to gradually reduce scaffolding for more of the targeted SEPs throughout the unit. This would include lessons or student activities throughout the unit in which students are provided heavier support/scaffolds early in the unit (e.g., using/developing the SEP as a whole group or with teacher assistance) and removing supports later in the unit as students further develop in the SEP. Supports for teachers to remove scaffolding throughout the unit for all students, including learners with disabilities, will allow students to use the SEP with greater independence by the end of the unit.

OVERALL CATEGORY II SCORE: **3** (0, 1, 2, 3)	
Unit Scoring Guide – Category II	
Criteria A-G	
3	At least adequate evidence for all criteria in the category; extensive evidence for at least two criteria
2	Some evidence for all criteria in the category and adequate evidence for at least five criteria, including A
1	Adequate evidence for at least three criteria in the category
0	Adequate evidence for no more than two criteria in the category

CATEGORY III

MONITORING NGSS STUDENT PROGRESS

III.A. MONITORING 3D STUDENT PERFORMANCES

III.B. FORMATIVE

III.C. SCORING GUIDANCE

III.D. UNBIASED TASK/ITEMS

III.E. COHERENT ASSESSMENT SYSTEM

III.F. OPPORTUNITY TO LEARN

How Can We Use Chemical Reactions to Design a Solution to a Problem?

EQuIP RUBRIC FOR SCIENCE EVALUATION

III.A. MONITORING 3D STUDENT PERFORMANCES

Elicits direct, observable evidence of three-dimensional learning; students are using practices with core ideas and crosscutting concepts to make sense of phenomena and/or to design solutions.

Rating for Criterion III.A. Monitoring 3D Student Performances	Extensive *(None, Inadequate, Adequate, Extensive)*

The reviewers found extensive evidence that the materials elicit direct, observable evidence of students using practices with core ideas and crosscutting concepts to make sense of phenomena and/or design solutions because each lesson contains one or more opportunities for the teacher to assess observable evidence of three-dimensional learning from students in a large group, small group, or individual setting. Some examples of these opportunities are listed below. Student performances are driven by a need to explain the flameless heater phenomenon or design a solution to a cheaper, homemade, flameless heater.

Related evidence includes:

- Lesson 2: “Ask students to take a moment to compare the other observations for each investigation to decide what data they can use as evidence to support their ideas and specifically how the data serve as evidence that chemical reactions are happening when these devices warm up. Encourage them to underline or make other annotations on their data tables or provide sticky notes for students to highlight the data that can work as evidence to support the idea that a chemical reaction happened. Lead a Building Understandings Discussion about our test results. Display slide R. Use questions, such as those that follow, to help the class make sense of this lesson’s investigations” (Teacher Edition, page 69). The class discussion and student observations and notes from the investigation serve as evidence of students learning in the following targeted elements:
    - SEP: *Conduct an investigation and/or evaluate and/or revise the experimental design to produce data to serve as the basis for evidence that meet the goals of the investigation.*
    - CCC: *The transfer of energy can be tracked as energy flows through a natural system.*
    - DCI: **PS1.B Chemical Reactions —** *Some chemical reactions release energy, others store energy.*
- Lesson 3: “Allow about 20 minutes for students to conduct their investigations. Circulate to hear what students are noticing … Make sure that students are using any free time to copy into their own science notebook the temperature data collected by the Data Recorder onto Data Table for Chemical Reactions Lab. … As you monitor groups, ask questions to help students focus on what they are trying to figure out rather than just focusing on the procedures. Here are example questions you might ask: What are you noticing about the temperature change? How do you think energy is transferring in this reaction? If you think about two systems involved, the reaction system and the thermometer, what direction is the energy transferred to make the temperature increase or decrease?” (Teacher Edition, page 89). This student performance (done in small groups) shows evidence for learning in the following targeted elements:

    - SEP: *Collect data to produce data to serve as the basis for evidence to answer scientific questions.*
    - CCC: *The transfer of energy can be tracked as energy flows through a natural system.*
    - DCI: **PS1.B Chemical Reactions** — *Some chemical reactions release energy, others store energy*.
- Lesson 3: "Have a few students share what they observed from the video and how that evidence compared to their predictions. Students should update their models, if needed, for each test compared to the 1X reaction and 1X food systems. Encourage students to use the particle model in their explanations for why the temperature increases even though they are using simple box models to show energy transfers and not particle models. Use the dialogue below as a guide and continue completing the class Energy Transfer Models on the board and encourage students to complete their models on the Energy Transfer Models handout. Have students jot down in the "Caption" column important ideas for each row… Give students time to complete their models and the caption for the last row of the handout as well as other rows they need to complete. Students should add what they have figured out to the caption in each row if they haven't done so already. Collect these handouts or notebooks from students once they are complete" (Teacher Edition, page 112–114). In this student performance, evidence for individual learning can be observed for the following targeted elements:
    - SEP: *Develop a model to describe unobservable mechanisms.*
    - CCC*: The transfer of energy can be tracked as energy flows through a natural system*
    - DCI*:* **PS3.B Conservation of Energy & Energy Transfer** —*The amount of energy transfer needed to change the temperature of a matter sample by a given amount depends on the nature of the matter, the size of the sample, and the environment.*
- Lesson 5: "Assign each member one of the readings and instruct them that they are responsible for reading and reporting on that resource to their group. Remind students that the purpose of this reading is to figure out the temperature range at which we want the food heated by our homemade heaters to be. Say, Based on our last discussion, it seems like these are the three main questions we think we need to answer in order to define our target temperature range. 1. What temperature is too hot? 2. Does food need to get to a certain temperature to avoid illness? 3. How warm does food need to get for people to enjoy the taste? Underline or use arrows to highlight important information in your reading and then tag it using these symbols to note which question the information is helping us answer. Add any other notes or questions you have as well… Share information in small groups to answer focal questions about food temperature. Display slide C after students finish their individual work and ask small groups to systematically discuss each focal question and record in their notebook what they have figured out. They should take turns sharing the information that each group member learned that helps answer the focal questions" (Teacher Edition, page 144). Student notes on their reading and the content of the small group discussions can be used for observable evidence of the following targeted elements:
    - SEP: *Analyze data to define an optimal operational range for a proposed object, tool, process, or system that best meets criteria for success*.
    - CCC: *Patterns can be used as evidence to support an explanation* (this CCC element is in the 3–5 grade band).
    - DCI: *The more precisely a design task's criteria and constraints can be defined, the more likely it is that the designed solution will be successful. Specification of constraints includes consideration of scientific principles and other relevant knowledge that is likely to limit possible solutions.*

- Lesson 6: "You all worked really hard to design and test your flameless heaters, but there are still ways we can improve them, right? … To help us think about how we can improve our designs we need to consider how different components or systems of our design are interacting with each other in order to transfer energy to heat up our food to 40-47 degrees Celsius. Let's return to our Energy Transfer Model to help us reflect on our designs so that next class we can begin to discuss ways of improving them. Pass out Exit Ticket. Allow time for students to map out their designs using the Energy Transfer Model. Collect Exit Ticket as students leave class" (Teacher Edition, page 183). These exit tickets provide observable, individual learning in the following elements:
    - SEP: *Apply scientific ideas or principles to design, construct, and/or test a design of an object, tool, process, or system*.
    - CCC: *Models can be used to represent systems and their interactions — such as inputs, processes, and outputs — and energy and matter flows within systems*.
    - DCI: **ETS1.C Optimizing the Design Solution** — *The iterative process of testing the most promising solutions and modifying what is proposed based on the test results leads to greater refinement and ultimately to an optimal solution*.
- Lesson 8: "Teams finish developing the Cascading Consequences Chart for the 2-3 design changes their team plans to make… Give students time to finish the chart with the rest of their team. teams will work to complete their Consequences Chart(s). If teams are still in strong disagreement about which changes to make, encourage teams to "split" and each make a Consequences Chart for the proposed changes they support, which will help the team decide on a final design using the chart as evidence" (Teacher Edition, page 206). This group–created Consequences Chart can show evidence of learning in the following elements:
    - SEP: *Evaluate competing design solutions based on jointly developed and agreed-upon design criteria*.
    - CCC: *Small changes in one part of a system might cause large changes in another part.*
    - DCI: *There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem*.
- Lesson 10: "Use the Design Testing Matrix to write an argument below that states whether incubator A will be sufficient to incubate sea turtle eggs effectively during relocation. Consider the criteria and constraints presented in the Design Testing Matrix and the advertised performance of incubator A in your argument" (Sea Turtle Assessment, page 3). This written individual assignment shows student learning in the following targeted elements:
    - SEP: *Make an oral or written argument that supports or refutes the advertised performance of a device, process, or system, based on empirical evidence concerning whether or not the technology meets relevant criteria and constraints.*
    - CCC: *The transfer of energy can be tracked as energy flows through a natural system.*
    - DCI: *There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem.*

Suggestions for Improvement

None

III.B. FORMATIVE	
Embeds formative assessment processes throughout that evaluate student learning to inform instruction.	
Rating for Criterion III.B. Formative	Extensive *(None, Inadequate, Adequate, Extensive)*

The reviewers found extensive evidence that the materials embed formative assessment processes throughout that evaluate student learning and inform instruction because frequent and varied formative assessment opportunities are explicitly called out in the Teacher Edition along with clear guidance for how the teacher can modify instruction to address different student responses. Sample student and class responses are often provided for various assessment opportunities. Equity issues are sometimes addressed for formative assessments.

Related evidence includes:

- Each lesson highlights multiple formative assessment processes in the "Assessment Opportunity" boxes. These boxes indicate which three-dimensional elements are targeted with the assessment, what the teacher should look for to indicate mastery, and "What to do" if students are not reaching the targets. Some examples are included below:
  - Lesson 5: "Building towards: 5.A.1 Analyze data by identifying patterns to define an optimal operational range for our homemade flameless heater designs that best meets criteria for success because the more precisely a design task's criteria and constraints can be defined, the more likely it is that the designed solution will be successful.
    <u>What to look and listen for:</u> Individual student notations, including tags, that align to the three focal questions Students using what they learned to build on the information presented by teammates that was obtained across the three resources Students using patterns they have identified to define upper and lower limits of the temperature range to which the food should be warmed
    <u>What to do:</u> Circulate during individual work time and remind students to use the tags and question prompts to focus their reading and notes. Consider providing a checklist with the focal questions and symbols (as shown on slide B) for students to check off as they read. As students are sharing information in small groups, encourage them to use the specific notes they recorded to contribute to the small-group discussion. As you circulate, use the question prompts to keep student conversation moving forward." (Teacher Edition, page 145).
  - Lesson 6: "6.B Apply scientific ideas, results from testing designs, and the interactions identified on system models to modify our designs in order to improve the flow of energy to food.
    <u>What to look and listen for:</u> Students should be able to connect and compare the results from testing their designs to the Energy Transfer Model. Students should be able to identify and map the different components in their designs to the different

systems in the Energy Transfer Model. Students should then be able to update their designs and explain ways to optimize the energy flow to the food.
What to do: If you notice that students are struggling with finding ways to optimize and improve their designs, follow up with these students in Lesson 7 as they compare and discuss in groups the differences in designs. Ask students to think about how these differences in designs impact how energy is being transferred to the food. Students will have another opportunity in Lesson 9 to connect their final designs to the Energy Transfer Model. So you can take that opportunity to revisit this idea and ask the students how each of their different models is helping them plan and test their proposed designs" (Teacher Edition, page 183).

- Lesson 8: "Building towards: 8.A Systematically evaluate competing design solutions based on jointly developed and agreed-upon design criteria using systemic processes to show how small changes in one design characteristic might cause unexpected changes in other design characteristics.
What to look for: As students are explaining their top two changes in teams, listen for each team member using the data from previous investigations and how that relates to the criteria and constraints to justify their choices. As teams begin their consensus discussion, listen for students to begin to surface potential negative effects of changes as they decide on which changes are best to implement. Look to see they are using their Design Testing Matrix to support their arguments.
What to do: Circulate while teams are working to look at individual student notebook entries and listen for discussions during consensus building … If students are only using the data to talk about more or less energy transfer, ask probing questions about why that data can be used as evidence to support their ranking to encourage them to put the data in the context of the criteria and constraints. If you don't hear students pushing back against others' ideas for changes during the consensus discussion, look at team members' written responses to find differences in suggested changes and set these changes up against each other while encouraging students to weigh in. Prompt them to check their Design Testing Matrix to consider any potential negative effects of a change …Use prompts similar to those below to encourage students to use evidence to be critical of choices…" (Teacher Edition, page 202).

- "Attending to Equity" sidebars emphasize support for ensuring equity in formative assessments and addressing individual needs and to ensure culturally responsive strategies. These sidebars are mostly focused on instructional strategies and there is very little teacher support for ensuring equity in assessment. A few examples of these sidebars are included below:
  - Lesson 1: "Supporting empathy and emotions: A unit where its phenomenon is connected to natural hazards is likely to elicit emotional stress from some students, either in terms of the empathy they feel for those affected or from experiencing a natural hazard directly or through the experiences of family and friends…If you have students who have traumatic experiences from natural hazards, consider some of the resources found in the Tsunami Unit" (Teacher Edition, page 28).
  - Lesson 3: "Supporting Universal Design for Learning: Use representations like color coding and/or letter or number coding to foreground parts of the model. Create a key to track what colors, symbols, or letter or number codes represent different parts of the system. The example model uses different colors to represent different types of particles. It is equally acceptable to use different shapes, drawn textures, or other ways to distinguish particles. What is important is that different particles are represented in

different ways. While color coding is a useful way to quickly reference the parts of the model, letter or number coding helps ensure accessibility for any student who may be color blind. If color coding is used, consider a color palette that uses orange, blue, black, or dark brown" (Teacher Edition, page 98–99).

- Lesson 8: "Universal Design for Learning: It is not always easy for students to make sense of the ideas of peers, especially when they are learning English, process language differently, lack confidence, or are uncertain. To encourage engagement, foster a culture in which exploring all student ideas is valued, especially those of students whose voices are not often heard. Set the expectation for all students to have areas with which they are not in total agreement or have further questions. Validate students who persist in questioning the team's thinking and bring up stories of scientists who famously questioned prevailing thought. For more information see http://stemteachingtools.org/brief/47" (Teacher Edition, pages 201–202).

Suggestions for Improvement

- Consider providing additional specific support for teachers to attend to equity issues in assessments and ensure that teachers can accurately assess three-dimensional learning for all learners, such as learners with disabilities and emerging multilingual learners.
- Consider providing assessment support for three-dimensional learning at the element level for all formative assessments rather than assessing students' use of the dimensions at the large-grain level.

III.C. SCORING GUIDANCE

Includes aligned rubrics and scoring guidelines that provide guidance for interpreting student performance along the three dimensions to support teachers in (a) planning instruction and (b) providing ongoing feedback to students.

Rating for Criterion III.C. Scoring Guidance	Adequate *(None, Inadequate, Adequate, Extensive)*

The reviewers found Adequate evidence that the materials include aligned rubrics and scoring guidelines that help the teacher interpret student performance for all three dimensions because a variety of guidance is provided including sample student responses, answer keys, and rubrics. Student exemplars are often provided but do not show examples of student responses at a range of different mastery levels. There is also some guidance to teachers for assessing grade-appropriate elements of all three dimensions, but some major assessments do not have scoring guides, rubrics, or feedback guidance.

Related evidence includes:

- Every key assessment task contains a "What to look for" and "What to do" section that gives general guidance on what the assessment target is in all three dimensions for the task. Exemplar student responses are provided for all classroom discourse/teacher oral questioning.
- Exemplar student responses are provided for many major assessment tasks such as:

  - Lesson 3: Chemical Reactions Lab
  - Lesson 3: Models and Captions activity
  - Lesson 4: Sample results for the Proportion of Reactants Investigation
  - Lesson 4: “Analyzing Our Data Collection” task
  - Lesson 6: Sample heater building instructions
  - Lesson 8: Optional Cascading Consequences Activity
- Lesson by Lesson Assessment Opportunities — This section in the Teacher Edition provides a lesson-level, three-dimensional performance expectation along with assessment guidance that includes when to check for understanding, and what to look and listen for (Teacher Edition, pages 243–248).
- Answer Key for Models and Captions — Three-dimensional learning targets are provided along with sample answers that are color-coded to match the elements of each dimension being assessed (Teacher Edition, pages 261–262).
- Exit Ticket Key – Targeted SEP, CCC, and DCI elements are identified. Sample answers are color coded to indicate assessment of an element (Teacher Edition, pages 273–274).
- The “Engineering Design Rubric” used in Lesson 6 and 9 has a row where all three dimensions are integrated. Students are given feedback after Lesson 6, however there is not specific guidance for the teacher in how to provide element-level feedback.
- The final written, summative assessment (Sea Turtle Assessment) has a Key showing expected/exemplar student responses. Several examples of acceptable student responses are given but does not show a range of student responses or have any guidance on how student learning should be scored for elements of the three dimensions.

Suggestions for Improvement

- Consider providing detailed rubrics for the significant assessment items, such as student models, exit tickets, or final summative assignment with a range of possible student responses for each of these assessments and support for modifying instruction for individual students based on their scoring in each dimension.
- Consider clarifying to the teacher in the scoring guidance the elements they are assessing and provide a range of possible student responses for each of these assessments and support for modifying instruction for individual students based on their scoring in each dimension.
- Consider focusing less on whole class oral questioning and more on individual student written work or visual models.
- Consider providing a way for students to track their progress over the unit in both the instructional materials and in the elements of each dimension

III.D. UNBIASED TASK/ITEMS

Assesses student proficiency using methods, vocabulary, representations, and examples that are accessible and unbiased for all students.

Rating for Criterion III.D. Unbiased Task/Items	Extensive *(None, Inadequate, Adequate, Extensive)*

The reviewers found extensive evidence that the materials assess student proficiency using accessible and unbiased methods, vocabulary, representations, and examples. Representations and scenarios are fair and appropriate for all students, with proper scaffolds to provide all students with background knowledge. A variety of modalities are used to collect information from students, but there are limited tasks that provide students with a choice of responses across multiple modalities.

Related evidence includes:

- All scenarios and phenomena presented in assessments are fair and unbiased.
- "Attending to Equity" sidebars help support teachers in ensuring that tasks are unbiased and accessible for all students and offer suggestions for modifications to tasks.
- Extra strategies for supporting students in vocabulary, reading, speaking, and listening skills are provided throughout the lessons in sidebars.
- Student responses utilize a variety of modalities across the lessons (verbal responses, drawn models, annotating notes, written responses)
- Guidance for Developing Your Word Wall (Teacher Edition, page 19) includes teacher support for introducing new and technical terms during the instruction.
- The readings found in Lesson 5 "How hot does food need to get so that people do not get sick?" "What temperatures cause scald burn injuries?" and "What temperature range makes food enjoyable to eat?" are found between 1010–1200 on the Lexile score, which is appropriate for 7th grade.
- In Lesson 9, students make their "How to" instructions for their heater design. Students are given the option to write, type, or make a video to explain the instructions for making their design. This shows a choice in modality in the student responses. This modification is listed as an "option" for the teacher. However, the option for students to choose how to present their instructions should be provided in all classrooms.

Suggestions for Improvement

Consider including additional modalities for supporting students receiving information and providing students with choices in the way they can respond to key tasks using their choice of modalities in order to make tasks more accessible to all students.

III.E. COHERENT ASSESSMENT SYSTEM

Includes pre-, formative, summative, and self-assessment measures that assess three-dimensional learning.

Rating for Criterion III.E. Coherent Assessment System	Extensive *(None, Inadequate, Adequate, Extensive)*

The reviewers found extensive evidence that the materials include pre-, formative, summative, and self-assessment measures that assess three-dimensional learning because a comprehensive assessment system overview is provided. Teachers are provided with a purpose and rationale for how, when, and why student learning is measured across the materials. Rationale for these assessments is provided in the "Assessment System Overview" (Teacher Edition, pages 240–248).

Multiple key assessment tasks are found in every lesson and are called out in the "Assessment Opportunity" boxes. All of these "Assessment Opportunity" tasks assess student learning in three dimensions and are used by students in either making sense of the flameless heater phenomenon or in solving the problem of an inexpensive, homemade, flameless heater. The unit contains pre-, formative, summative, and self-assessment tasks. At least one example of each type is listed here for evidence, although there are many more assessment opportunities throughout the unit.

- Pre-Assessment
  - Lesson 1: "If you did not get to see every student's initial design while they were working to create them, listen in while groups are talking to check out the designs you haven't seen yet. The goal is to gather formative pre-assessment data about where students are right now with the practice of modeling and see whether they have included systems thinking or ideas about chemical processes in their design models. The next several lessons will focus specifically on these ideas, so having this pre-assessment data will help you prepare to best meet your students where they are" (Teacher Edition, page 44).
  - Several points throughout the lessons refer to connections from previous units. For example, in Lesson 2 — "Purpose of this discussion: (1) Use what we recalled from OpenSciEd Unit 6.2: How can containers keep stuff from warming up or cooling down? (Cup Design Unit) combined with OpenSciEd Unit 7.1: How can we make something new that was not there before? (Bath Bombs Unit) and the investigations we completed in this lesson to create a model that describes energy flow in an MRE system and (2) use the model we created and the information we learned from our investigations in this lesson to decide on our next design steps." (Teacher Edition, page 71). In Lesson 3 — "Purpose of this discussion: (1) Use what we recalled from OpenSciEd Unit 6.2: How can containers keep stuff from warming up or cooling down? (Cup Design Unit) combined with OpenSciEd Unit 7.1: How can we make something new that was not there before? (Bath Bombs Unit) and the investigations we completed in this lesson to create a model that describes energy flow in an MRE system and (2) use the model we created and the information we learned from our investigations in this lesson to decide on our next design steps" (Teacher Edition, page 85).
- Formative Assessment
  - Lesson 2: "Throughout the lesson, try to elicit responses from everyone in the class so that you can formatively assess which students may need more support and guidance when planning future investigations" (Teacher Edition, page 64).

  - Lesson 6: "Purpose of this discussion: (1) Use what we recalled from OpenSciEd Unit 6.2: How can containers keep stuff from warming up or cooling down? (Cup Design Unit) combined with OpenSciEd Unit 7.1: How can we make something new that was not there before? (Bath Bombs Unit) and the investigations we completed in this lesson to create a model that describes energy flow in an MRE system and (2) use the model we created and the information we learned from our investigations in this lesson to decide on our next design steps" (Teacher Edition, page 179).
- Summative Assessment
  - Lesson 10 (Sea Turtle Assessment): "This is a summative assessment. However, if students need extra support, you can choose to allow them to use the classroom consensus model, their science notebooks, as well as their responses to the Exit Ticket from Lesson 6 to help them complete the sea turtle transfer task. Since the phenomenon they will be exposed to will be new, they will not find exact answers to the assessment in their notes, and allowing this support may help students make explicit connections to the work they did in class" (Teacher Edition, page 236).
- Self-Assessment
  - Lesson 6: "After testing, we complete a self-assessment of how well our team works as engineers and how well we individually meet expectations as teammates" (Teacher Edition, page 7).
  - Lesson 9: "Complete the Engineering Design Rubric in teams. Display slide Q. Distribute Engineering Design Rubric to each team. Say, Let's see what kind of progress we've made on our engineering work. Take some time with your team to assess how well you've been able to apply what you've figured out about what engineers do. I will use this same assessment (rubric) to assess your work, as well. Continue to follow our expectations for teamwork as you decide together how to rate your work, and remember, it's not assessing how successful our design was, but how well we were able to apply what we've learned about what engineers do. Give teams time to complete the rubric and hand it in as they finish for you to use, as well" (Teacher Edition, page 227).

Suggestions for Improvement
None

III.F. OPPORTUNITY TO LEARN

Provides multiple opportunities for students to demonstrate performance of practices connected with their understanding of disciplinary core ideas and crosscutting concepts and receive feedback.

Rating for Criterion III.F. Opportunity to Learn	Extensive *(None, Inadequate, Adequate, Extensive)*

The reviewers found extensive evidence that the materials provide multiple opportunities for students to demonstrate performance of practices connected with their understanding of core ideas and crosscutting concepts because there are multiple opportunities for students to demonstrate their knowledge and growth in proficiency over time of the focus SEP and CCC as they solve the design problem. The design problem requires students to develop and use the claimed DCIs.

Related evidence includes:

- Students demonstrate their proficiency of the multiple elements of the SEP of **Constructing Explanations and Designing Solutions** over the course of the material. It can be found in Lessons 1, 6, 8, and 9. For example:
  - Lesson 1: Students develop an initial design for their solution to the homemade, flameless heater problem.
  - Lesson 6: Students use the "Engineering Design Rubric" to self-assess their design solutions to the unit problem. This same rubric is used again later in Lesson 9 after students have had a chance to improve their design solutions and is used by the teacher as an assessment of their design as well.
- Students demonstrate their understanding of the CCC of **Energy and Matter** over the course of the materials in Lessons 1, 2, 3, 6, 9, and 10.
- Students use their understanding of DCIs, **ETS1.A: Defining and Delimiting Engineering Problems, ETS1.B: Developing Possible Solutions, ETS1.C: Optimizing the Design Solution,** and **PS1.B: Chemical Reactions** throughout the unit in tandem with the CCC **Energy and Matter** and the SEP **Planning and Carrying Out Investigations** to create an initial design, and then a revised design of the flameless heater (Lesson 9). Students then demonstrate their growth on a final assessment where students apply their learning to a new situation (Lesson 10). Although students complete a team assessment, "Engineering Design Rubric," at the end of Lesson 9, students do not have the opportunity to construct new learning or improve their performance in preparation for the assessment in Lesson 10.
- Students have multiple explicit opportunities to incorporate feedback they receive to improve their performance. For example:
  - Lesson 7: Students provide peer feedback to each other on their Flameless Heater designs.
  - Lesson 8: Students use the Peer Feedback on Designs document to optimize their design solution before retesting it in Lesson 9.
- Students have multiple opportunities to receive teacher written feedback. For example, in Lesson 3 with the Energy Transfer Models, Lesson 6 with the Exit Ticket, and Lesson 10 with the Sea Turtle Assessment.

Suggestions for Improvement

None

OVERALL CATEGORY III SCORE: 3 (0, 1, 2, 3)	
Unit Scoring Guide – Category III	
Criteria A-F	
3	At least adequate evidence for all criteria in the category; extensive evidence for at least one criterion
2	Some evidence for all criteria in the category and adequate evidence for at least five criteria, including A
1	Adequate evidence for at least three criteria in the category
0	Adequate evidence for no more than two criteria in the category

SCORING GUIDES

SCORING GUIDES FOR EACH CATEGORY

UNIT SCORING GUIDE – CATEGORY I (CRITERIA A-F)

UNIT SCORING GUIDE – CATEGORY II (CRITERIA A-G)

UNIT SCORING GUIDE – CATEGORY III (CRITERIA A-F)

OVERALL SCORING GUIDE

Scoring Guides for Each Category

Unit Scoring Guide – Category I (Criteria A-F)	
3	At least adequate evidence for all of the unit criteria in the category; extensive evidence for criteria A–C
2	At least some evidence for all unit criteria in Category I (A–F); adequate evidence for criteria A–C
1	Adequate evidence for some criteria in Category I, but inadequate/no evidence for at least one criterion A–C
0	Inadequate (or no) evidence to meet any criteria in Category I (A–F)

Unit Scoring Guide – Category II (Criteria A-G)	
3	At least adequate evidence for all criteria in the category; extensive evidence for at least two criteria
2	Some evidence for all criteria in the category and adequate evidence for at least five criteria, including A
1	Adequate evidence for at least three criteria in the category
0	Adequate evidence for no more than two criteria in the category

Unit Scoring Guide – Category III (Criteria A-F)	
3	At least adequate evidence for all criteria in the category; extensive evidence for at least one criterion
2	Some evidence for all criteria in the category and adequate evidence for at least five criteria, including A
1	Adequate evidence for at least three criteria in the category
0	Adequate evidence for no more than two criteria in the category

How Can We Use Chemical Reactions to Design a Solution to a Problem?

EQuIP RUBRIC FOR SCIENCE EVALUATION

OVERALL SCORING GUIDE	
E	**Example of high quality NGSS design—**High quality design for the NGSS across all three categories of the rubric; a lesson or unit with this rating will still need adjustments for a specific classroom, but the support is there to make this possible; exemplifies most criteria across Categories I, II, & III of the rubric. (total score ~8–9)
E/I	**Example of high quality NGSS design if Improved—**Adequate design for the NGSS, but would benefit from some improvement in one or more categories; most criteria have at least adequate evidence (total score ~6–7)
R	**Revision needed—**Partially designed for the NGSS, but needs significant revision in one or more categories (total ~3–5)
N	**Not ready to review—**Not designed for the NGSS; does not meet criteria (total 0–2)